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Rio Blanco Oil Shale Company

MODULAR DEVELOPMENT PHASE MONITORING REPORT SEVEN

VOLUME 1 of 4

December 1979–November 1980 Year End Report

Gulf Oil Corporation / Standard Oil Company (Indiana)
A General Partnership
2851 South Parker Road, Aurora, Colorado, 80014

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RIO BLANCO OIL SHALE COMPANY
MODULAR DEVELOPMENT PHASE
MONITORING REPORT 7

December 1979 - November 1980
YEAR-END REPORT

Prepared by:
RIO BLANCO OIL SHALE COMPANY
AURORA, COLORADO

March 31, 1981

Contributors:

Gary E. Bertolin, RBOSC
David A. Boyce, RBOSC
W. Jack Clark, RBOSC
James W. Ericson, RBOSC
Rosielea Gash, RBOSC
James R. Johnson, RBOSC
Becky J. McCormick, RBOSC
Marla M. Moody, RBOSC
Craig O. Laurie, RBOSC
Marji J. Randall, RBOSC
Judy M. Rodreick, RBOSC
RBOSC Drafting Department
Kaman Tempo
Mariah Associates
Judith S. Warner, PhD

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SECTION 1
INTRODUCTION

In 1969, the U.S. Department of the Interior (USGS) initiated planning for a prototype oil shale leasing program. Under this program, Gulf Oil Corporation and Standard Oil Company (Indiana) acquired the oil shale lease for Tract C-a in the Piceance Creek Basin of northwest Colorado in 1974. These two companies are now developing the tract under a general partnership called the Rio Blanco Oil Shale Company (RBOSC).

Since its inception in 1974, RBOSC has been conducting extensive programs to collect environmental data. Between October 1974 and September 1976, two years of baseline data were gathered. From September 1976 through August 1977, interim environmental data were collected during the period in which RBOSC had suspended tract development activities. In August 1977, RBOSC launched their Modular Development Phase (MDP) Environmental Monitoring Program. The first report of MDP environmental activities (September - November 1977) was published in February 1978. Subsequent reports were published in September 1978; March and August 1979; and March and August 1980. The current report represents RBOSC's seventh MDP Monitoring Report, and covers the period from December 1979 - November 1980.

The RBOSC MDP Environmental Monitoring Program provides data on air quality, meteorology, terrestrial ecology, aquatic ecology, hydrology, and special studies. Monitoring program designs are based on analysis of baseline and interim studies data, an assessment of probable developmental impacts, and recommendations from the Oil Shale Office (OSO). The monitoring conducted during this reporting period was in accordance with Revision 5.2 of the RBOSC Modular Development Phase Environmental Monitoring Program Scope of Work, dated March 30, 1979 and approved by the OSO on April 26, 1979 with 17 Conditions of Approval. This scope of work reflects the environmental monitoring philosophy set forth in RBOSC's Detailed Development Plan (DDP).

Major responsibility for monitoring program activities rests with personnel in RBOSC Environmental Affairs Department. However, several consultants were used in various capacities during this reporting period. They include: Kaman Tempo

(Environmental Hydrology), Morrison Knudsen (Operational Hydrology), Mariah Associates (Aquatic studies), USGS (Surface water gaging station program), and Dr. J.S. Warner (statistical review). Section 4.0 - Aquatic Studies - was prepared by Mariah Associates; Section 5.0 - Hydrology Studies - was prepared by Kaman Tempo and includes the USGS water data. Visibility studies were carried out in a joint effort with Cathedral Bluffs Shale Oil Venture (Tract C-b).

Data collected during MDP monitoring studies are reported semi-annually, in a mid-year and a year-end report. Monitoring Report 7, the third year-end interpretative report, presents and summarizes the data collected during the 1980 reporting year, a summary of these data, statistical comparisons between seasons, years, and locations, where applicable, and assessments of any impacts which may have been caused by development activities.

Objectives of the monitoring program are presented herein. Methods are presented only if they differ from those presented in previous RBOSC MDP Monitoring Reports, if clarification is required, or if methods have not been previously reported. The "Special Studies" section discusses studies that are conducted periodically, as necessary, and provides a format for presenting data that might otherwise be obscured. Experimental revegetation studies data, previously provided in a separate report, are presented in Section 6.2.

Volume 1 of this report contains eight sections as follows:

Section 1 - Introduction
Section 2 - Atmospheric Studies
Section 3 - Terrestrial Studies
Section 4 - Aquatic Studies
Section 5 - Hydrology Studies
Section 6 - Special Studies
Section 7 - Ecological Interactions
Section 8 - Summary

Volumes 2, 3 and 4 contain the following data appendices:

2-1 Air Quality Data
2-2 Meteorological Data
2-5 Visibility Data
3-1 Vegetation Data
3-2 Fauna Data
4-1 Aquatic Abiotic Data
4-2 Aquatic Biotic Data
5-1 Surface Water Data
5-2 Ground Water Data
6-2 Revegetation Data

SECTION 2
ATMOSPHERIC STUDIES

The Tract C-a atmospheric studies program consists of two elements: (1) measurements of total suspended particulate matter and certain gaseous chemical compounds, and (2) measurements of selected meteorological parameters. The monitoring locations were originally established to measure the ambient air quality generally upwind and somewhat removed from the expected tract development, and at points where tract developments might have an effect on the air quality. Simultaneous meteorological measurements are being made to allow evaluations of air quality changes and for the prediction of the dispersion of emissions resulting from tract development.

Air quality and meteorological data have been obtained since February 1975 from monitoring instruments located on or near Tract C-a. The first two years of data collection make up the baseline data set. Data from the baseline period were obtained at four locations around the tract. Following the baseline period, an interim data acquisition program was established to cover an interval during which the tract development lease conditions were modified and partially suspended. During the interim period (February through August 1977), a single air quality and meteorological monitoring station was operated to maintain data continuity.

The current program is part of the Modular Development Phase (MDP). The level of activity on the tract, principally construction work, has increased significantly during the MDP period. The monitoring program has been expanded in order to measure possible effects of increased tract activity on the ambient air quality. Two of the sites that had been deactivated for the interim period were refitted with meteorological instrumentation and put back on-line during the first quarter of the MDP. In addition, one of the reactivated meteorological sites has been refitted with a complete set of air quality instrumentation (Table 2-1).

Table 2-1. Air Studies Monitoring Parameters and MDP Program Schedule, Tract C-a

Parameter	Location	Start Date	Frequency
Sulfur Dioxide	Site 1	Sept. 1977	Continuously
	Site 3	Jan. 1978	Continuously
Nitrogen Oxides	Site 1	Sept. 1977	Continuously
	Site 3	Feb. 1980	Continuously
Nitric Oxide	Site 1	Sept. 1977	Continuously
	Site 3	Feb. 1980	Continuously
Hydrogen Sulfide	Site 1	Nov. 1977	Continuously
	Site 3	Jan. 1978	Continuously
Carbon Monoxide	Site 1	Oct. 1977	Continuously
	Site 3	Nov. 1979	Continuously
Hydrocarbons(1)	Site 1	Sept. 1977	Continuously
Ozone	Site 1	Sept. 1977	Continuously
	Site 3	Nov. 1977	Continuously
Particulates	Sites 1, 2, 3	Dec. 1977	Every 3rd day
	Site 6 1/	Dec. 1977	Every 3rd day
Wind direction (10m)	Sites 1, 2, 3	Sept. 1977	Continuously
Wind direction (60m)	Site 1	Sept. 1977	Continuously
Wind speed (10m)	Sites 1, 2, 3	Sept. 1977	Continuously
Wind speed (60m)	Site 1	Sept. 1977	Continuously
Wind sigma (10m)	Site 1	Sept. 1977	Continuously
Ambient temperature (10m)	Sites 1, 2, 3	Sept. 1977	Continuously
Temperature differential (10-60m)	Site 1	Sept. 1977	Continuously
Precipitation	Sites 1, 2, 3 & other selected locations	Oct. 1977	By event
Snow depth and accumulation	Sites 1, 2, 3	Nov. 1978	By event
Solar radiation	Site 1	Sept. 1977	Continuously
Dewpoint (10m)	Site 1	July 1978	Continuously
Visibility	Visibility Shelter	Spring 1978	Semi-annually
Noise	16 locations on tract	Jan. 1978	Quarterly

1/ discontinued by agreement with DCM-OS

2.1 AIR QUALITY

Air quality monitoring is being conducted on and near Tract C-a to measure the concentrations of certain pollutants which may be emitted by tract operations. The ambient air quality monitoring network consists of two locations where gaseous constituents are measured (Sites 1 and 3) and three locations where total suspended particulate (TSP) concentrations are measured (Sites 1, 2, and 3) (See Environmental Monitoring Sites Map 1 - Physical, in map pocket.) Sites 1 and 2 generally measure background ambient air quality, while Site 3 is located in a broad gulch that may have some air quality changes due to downvalley flow of pollutants from the main development area in the center of the tract.

All of the air quality data, with the exception of the particulate data, is collected by automatic monitoring equipment and recorded by a data acquisition system on digital computer tape and backup strip charts. The data on the digital tape are averaged into hourly values. High volume samplers are used to collect 24-hour samples of TSP concentrations every third day at three sites.

A cooperative visibility study (with Tract C-b) has been conducted each spring and fall since 1978 as part of the air studies program. In 1979, an addition was made to the study by measuring the visual range with a telephotometer as well as with the traditional photometric technique. These data will allow comparisons to be made between the two measurement techniques.

Starting early in 1980, analyzers to monitor carbon monoxide, nitric oxide, and nitrogen oxides were re-installed at Site 3 and included in the data acquisition system. There is now a full complement of operational air quality analyzers at both Sites 1 and 3 (Table 2-1).

Air quality data taken during the most recent six-month period (the twelfth and thirteenth quarters of the MDP program) are presented in Appendices 2-1.1 (gaseous constituents) and 2-1.2 (total suspended particulates). A time series plot for the 1979 ozone data at Site 1 is included in a separate volume.

As part of the year-end report, an extensive analysis has been carried out on the data obtained during the most recent four quarters of the MDP program (December 1979-November 1980, hereafter referred to as the current year). Comparisons have been made among the current year, the baseline period (February 1975-January 1977), and the two previous years of the MDP period (December 1977 - November 1978 and December 1978 - November 1979).

When analyzing a data set, it is important to evaluate the data in relation to the limitations of the instrumentation. This is particularly true of air quality data gathered in a pristine environment, such as found at Tract C-a. Ambient concentrations of several gaseous constituents usually are at or below the minimum measurement capability of air quality monitoring instruments. Statistical analyses may therefore not be applicable to these data sets.

A quantitative measure has therefore been developed to use as a conservative minimum level, below which there is essentially no probability that the values represent real and valid data. This level, called the threshold of detection, is defined as twice the noise level of the instrument. The threshold of detection can thus be used to determine if there is a sufficient number of valid data points to warrant further statistical analyses.

It should be emphasized that the threshold of detection is a conservative measure to use in determining data validity. It is arbitrarily defined as twice the noise level of the instrument to take into account the errors or uncertainties which develop when measurements are taken near the minimum detectable limit of any monitor. These uncertainties are extremely difficult to quantify, but it is quite likely that the threshold of detection as defined above represents an optimal situation. Consequently, this value, determined independently for each instrument, is a conservative measure of data validity. That is, some data that are not significant (within the noise of the measurement system) may be retained, but no valid data will be arbitrarily discarded (due to tests of significance set too high).

The ultimate goal is to define confidence limits around the data collected by each instrument, which will serve as realistic criteria with which to judge the validity of the data. Threshold of detection values for each instrument are given in Table 2-2. These detection limits can be used as a guide to determine how much of the data can be considered statistically valid. The significance of

Table 2-2. Air Quality Instrumentation used at Tract C-a, with the Threshold of Detection for each Monitor

Variable	Manufacturer	Model	Technique	Lower Detectable Limit (ppm)
SO_2	Thermo Electron Corporation	43	Pulsed Fluorescence	0.002
H_2S	Thermo Electron Corporation	45	Pulsed Fluorescence	0.002
NO/NO_x	Bendix	8101-B	Chemiluminescence	0.005
Photochemical Oxidant (O_3)	Bendix	8002	Chemiluminescence	0.001
CO	Bendix	8501-5CA	Nondispersive infrared detection	0.5

the data for each parameter will be discussed separately in the appropriate section below. In some instances, the data sets are at or below the minimum detectable limit of the instrument, which limits the analysis that can be applied to the data.

A. Sulfur Dioxide

1. Objectives

The objective of monitoring for sulfur dioxide is to establish the ambient air concentration prior to and during tract development. The existing sulfur dioxide levels and associated environmental effects can be used as a basis for comparison to assess future environmental changes that may be related to any increase in the concentration of sulfur dioxide.

2. Methods

The methods followed for collection of sulfur dioxide data were described in RBOSC MDP Monitoring Report 5 and are not repeated herein.

3. Results and Discussion

The new pulsed fluorescent SO_2 monitors installed at Sites 1 and 3 last year have proven to be excellent instruments, and the data recovery has been good. Table 2-3 provides mean, maximum, and minimum concentrations of air quality variables monitored at Tract C-a during the current year. The table shows that maximum concentrations of SO_2 were 0.022 ppm at Site 1 and 0.013 ppm at Site 3, while mean concentrations were 0.002 and 0.003 ppm at Sites 1 and 3, respectively.

Thus, almost all of the SO_2 concentrations monitored during the current year were at or below the threshold of detection for the instruments.

The highest SO_2 concentration recorded during the year, 0.022 ppm at Site 1 on October 19, probably resulted from SO_2 emissions during the burning of retort 0. This conclusion is based upon a review of the wind direction data at Site 1, which show an easterly wind at 0900 hours, which would transport the stack

Table 2-3. Annual Summary of Air Quality Data Collected Between December 1979 and November 1980, Tract C-a

Parameter	Units	Minimum[1/]	Maximum[1/]	Arithmetic Mean
		Site 1		
O_3	ppm	0.013	0.077	0.046
CO	ppm	0.5	0.9	0.5
NO	ppm	0.005	0.061	0.005
NO_x	ppm	0.005	0.062	0.005
H_2S	ppm	0.002	0.012	0.003
SO_2	ppm	0.002	0.022	0.002
TSP[3/]	$\mu g/m^3$	2	61	13.[2/]
		Site 2		
TSP[3/]	$\mu g/m^3$	1	61	12.[2/]
		Site 3		
O_3	ppm	0.003	0.070	0.035
CO	ppm	0.5	0.5	0.5
NO	ppm	.005	.024	.005
NO_x	ppm	.005	.021	.005
H_2S	ppm	0.002	0.060	0.004
SO_2	ppm	0.002	0.013	0.003
TSP[3/]	$\mu g/m^3$	1	96	18.[2/]

[1/] Hourly average

[2/] Geometric Mean

[3/] 24-hour averages

emissions to Site 1. It should be noted, however, that this concentration is near the threshold of detection of the instrument, being only about four percent of full scale.

Comparison of the current year's data (Table 2-3) with data from earlier years (December 1978 - November 1979, Table 2-4; December 1977 - November 1978, Table 2-5; February 1975 - January 1977, Table 2-6) show that yearly maximum and average SO_2 concentrations have been similar in each of the years. The highest concentration found during the five years of data summarized in this report is 0.11 ppm, which occurred during the baseline period. The yearly means for all four years have been at or below the threshold of detection of the monitoring equipment.

B. Hydrogen Sulfide

1. Objectives

The objective of monitoring hydrogen sulfide in the ambient air on the tract is to establish the background value. Tract development, which will involve recovery of sulfur-bearing organics, may release hydrogen sulfide into the ambient air. Concentrations of this constituent in the future may be compared to pre-development conditions to assess environmental impacts.

2. Methods

The methods for collection of hydrogen sulfide data were described in RBOSC MDP Monitoring Report 5 and are not repeated herein.

3. Results and Discussion

Table 2-3 shows that maximum concentrations of H_2S during the current year were 0.012 ppm at Site 1 and 0.060 ppm at Site 3. Annual mean concentrations were 0.003 and 0.004 ppm at Sites 1 and 3, respectively.

Comparisons with previous data show that the mean annual concentrations have remained at or below the threshold of detection for the entire study period. Marginally higher maximum H_2S concentrations have occurred at Site 3 during the

Table 2-4. Annual Summary of Air Quality Data Collected Between December 1978 and November 1979, Tract C-a

Parameter	Units	Minimum[1/]	Maximum[1/]	Arithmetic Mean
		Site 1		
O_3	ppm	0.018	0.080	0.049
CO	ppm	0.5	1.5	0.5
NO	ppm	0.005	0.048	0.005
NO_x	ppm	0.005	0.048	0.005
H_2S	ppm	0.01	0.01	0.01
SO_2	ppm	0.01	0.01	0.01
TSP[3/]	$\mu g/m^3$	1	303	11.[2/]
		Site 2		
TSP[3/]	$\mu g/m^3$	1	87	12.[2/]
		Site 3		
O_3	ppm	0.005	0.076	0.038
H_2S	ppm	0.01	0.14	0.01
SO_2	ppm	0.01	0.09	0.01
TSP[3/]	$\mu g/m^3$	3	192	21.[2/]

[1/] Hourly average

[2/] Geometric Mean

[3/] 24-hour averages

Table 2-5. Annual Summary of Air Quality Data Collected Between December 1977 and November 1978, Tract C-a

Parameter	Units	Minimum[1/]	Maximum[1/]	Arithmetic Mean
		Site 1		
O_3	ppm	0.017	0.088	0.057
CO	ppm	0.5	0.5	0.5
NO	ppm	0.005	0.016	0.006
NO_x	ppm	0.005	0.023	0.006
H_2S	ppm	0.01	0.04	0.01
SO_2	ppm	0.01	0.03	0.01
TSP[3/]	$\mu g/m^3$	1.	59.	14.[2/]
		Site 2		
TSP[3/]	$\mu g/m^3$	1.	60.	13.[2/]
		Site 3		
O_3	ppm	0.004	0.072	0.038
H_2S	ppm	0.01	0.55	0.01
SO_2	ppm	0.01	0.11	0.01
TSP[3/]	$\mu g/m^3$	1.	160.	26.[2/]

[1/] Hourly average

[2/] Geometric Mean

[3/] 24-hour averages

Table 2-6. Annual Summary of Air Quality Data Collected Between February 1975 and January 1977 (Baseline), Tract C-a

Parameter	Units	Minimum[2]	Maximum[2]	Arithmetic Mean
		Site 1		
O_3	ppm	0.000	0.068	0.034
CO	ppm	0.000	4.2	0.6
NO	ppm	0.000	0.237	0.008
NO_x	ppm	0.000	0.234	0.009
H_2S	ppm	0.000	0.05	0.01
SO_2	ppm	0.000	0.09	0.01
TSP[3]	$\mu g/m^3$	1	211	9[2]
		Site 2		
TSP[3]	$\mu g/m^3$	1	102	9[3]
		Site 3		
O_3	ppm	0.000	0.089	0.031
CO	ppm	0.000	6.0	0.6
NO	ppm	0.000	0.159	0.006
NO_x	ppm	0.000	0.154	0.006
H_2S	ppm	0.000	0.03	0.01
SO_2	ppm	0.000	0.05	0.01
TSP[3]	$\mu g/m^3$	1	281	15[2]

[1] Hourly Average

[2] Geometric Mean

[3] 24-hour average

MDP. This is probably related to the surface flow of groundwater discharge containing reduced sulfur compounds past Site 3.

C. Nitrogen Oxides

1. Objectives

Nitrogen oxides are monitored to establish the existing natural background levels prior to major tract development and operation. Tract operations will involve substantial combustion with the resultant generation of nitrogen oxides. Nitric oxide in the presence of sunlight and hydrocarbons may be a mechanism for smog production.

2. Methods

The methods followed for collection of nitrogen oxides data were described in RBOSC MDP Monitoring Report 2 and are not repeated herein.

3. Results and Discussion

The concentrations of both nitric oxide and nitrogen oxides were below the threshold of detection most of the time during the current year, so that the annual mean of both these variables at Site 1 is at or below 0.005 ppm. These values are similar to those obtained during previous years--no annual mean for either NO or NO_x exceeded 0.01 ppm. The maximum concentrations measured during the year were 0.061 ppm for NO and 0.062 ppm for NO_x.

During the early part of the current year, an NO/NO_x analyzer was installed at Site 3, so that approximately 10 months of data at that station have been collected. The mean concentrations of NO and NO_x measured during the current year at Site 3 were both 0.005 ppm. The maximum concentrations were 0.024 ppm for NO and 0.021 ppm for NO_x.

A review of the maximum NO and NO_x concentrations recorded during the year showed that both occurred at Site 1 on May 21 at 2200 hours. For several hours prior to that time, winds at Site 1 were northerly. Consequently, these slightly elevated concentrations probably were a result of emissions from

diesel generators on another operator's oil and gas drilling rig located a few hundred yards to the northwest of Site 1, which was operating on a 24-hour schedule.

D. Carbon Monoxide

Carbon monoxide results from the incomplete oxidation of carbon during combustion. Vehicular use and fuel combustion during tract development may result in the emission of carbon monoxide in the tract area.

1. Objectives

Carbon monoxide is monitored to establish the ambient air concentration of this constituent prior to and during tract development activities.

2. Methods

The methods followed for collection of carbon monoxide data were described in RBOSC MDP Monitoring Report 2 and are not repeated herein.

3. Results and Discussion

A CO analyzer was installed during the current year at Site 3 to supplement the data collected at Site 1. At both sites, the measured concentration of CO was at or below the threshold of detection most of the time.

Maximum concentration at Site 1 was 0.9 ppm, and 0.5 ppm at Site 3. The mean concentrations of CO at both sites were 0.5 ppm. These concentrations are very similar to those measured in earlier years.

E. Ozone

1. Objectives

Ozone monitoring is conducted to determine the ambient air concentration of this constituent prior to and during tract development and operation. The

potential emissions of nitrogen oxides coupled with hydrocarbons in strong sunlight can produce photochemical reactions.

2. Methods

The methods followed for collection of ozone data were described in RBOSC MDP Monitoring Report 2 and are not repeated herein.

3. Results and Discussion

The range of ozone concentrations recorded during the current year, as shown in Table 2-3, was 0.013 to 0.077 ppm at Site 1 and 0.003 to 0.070 ppm at Site 3. The mean concentration at Site 1 was 0.046 ppm and at Site 3 was 0.035 ppm. Thus, there were no violations of the primary or secondary National Ambient Air Quality Standard (NAAQS) for ozone (0.12 ppm) at either site. These concentrations are comparable to those found during the previous monitoring periods (Tables 2-3 through 2-5).

In addition to the difference in mean ozone concentrations between Site 1 and Site 3, there is also a difference in the distribution of ozone concentrations between the two sites. As illustrated in Figures 2-1 through 2-5, there is a diurnal cycle of mean hourly ozone concentrations at both sites. Although Sites 1 and 3 both show a maximum ozone concentration during the day and a minimum at night, the average diurnal change is much smaller at Site 1 (0.008 ppm at Site 1 vs. 0.023 ppm at Site 3).

Figures 2-6 through 2-10 are histograms of the hourly ozone concentrations at both sites during each of the four seasons and for the entire year. The ozone concentrations are shown in 0.01 ppm increments. Site 1 shows a fairly sharp peak in the distribution during each season, with a shift to higher concentrations during the spring and summer. Site 3, on the other hand, shows a much broader distribution of ozone concentrations but with the same shift to high concentrations during the warm seasons. This ozone peak during the summer is a common phenomenon (U.S. EPA 1978). These histograms are another way of illustrating the pronounced diurnal variations of ozone concentrations typical of Site 3 and the relatively constant concentrations typical of Site 1.

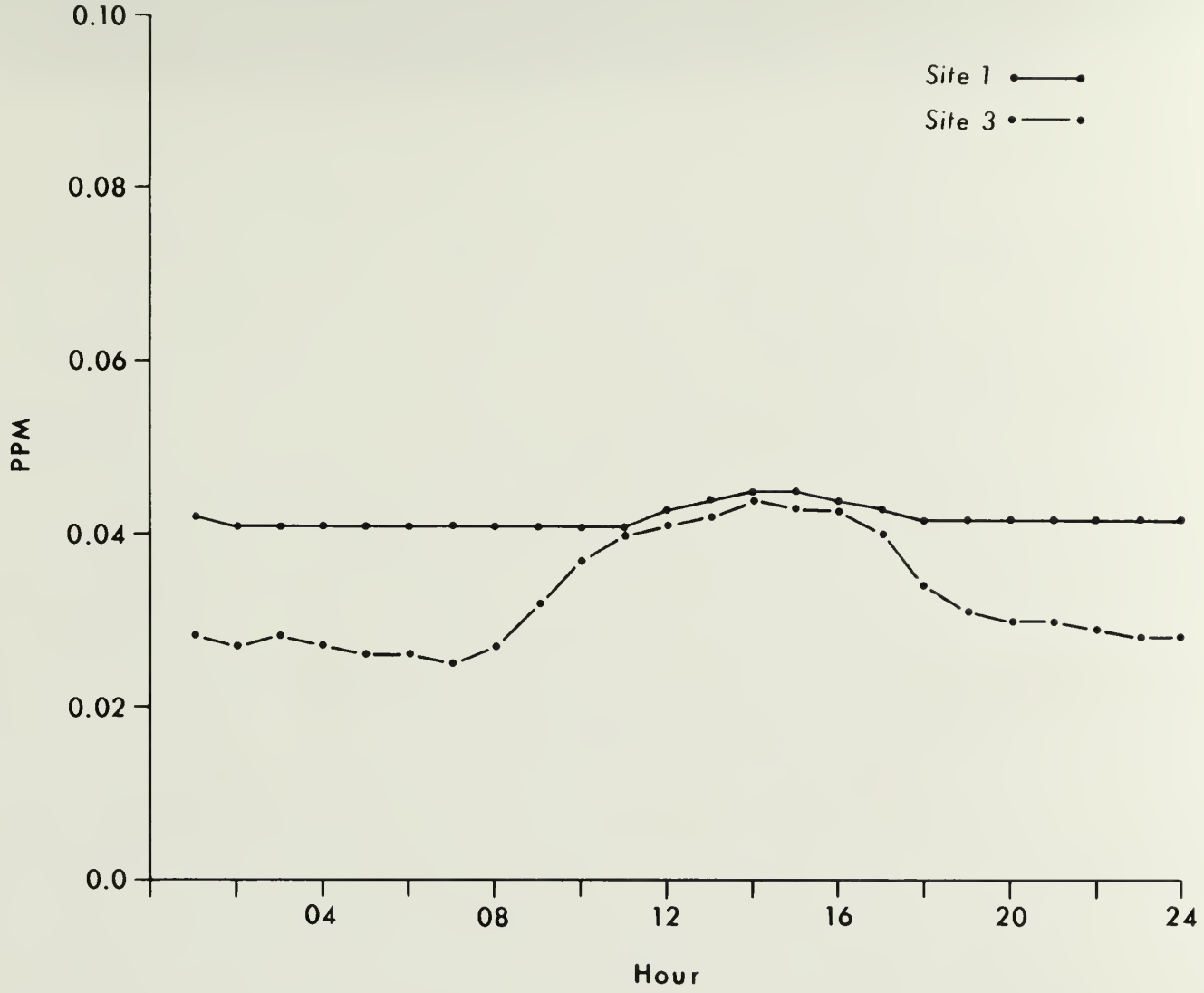

Figure 2-1. Diurnal Variation of Mean Hourly Ozone Concentrations at Sites 1 and 3, Winter (Dec 1979 and Jan-Feb 1980), Tract C-a

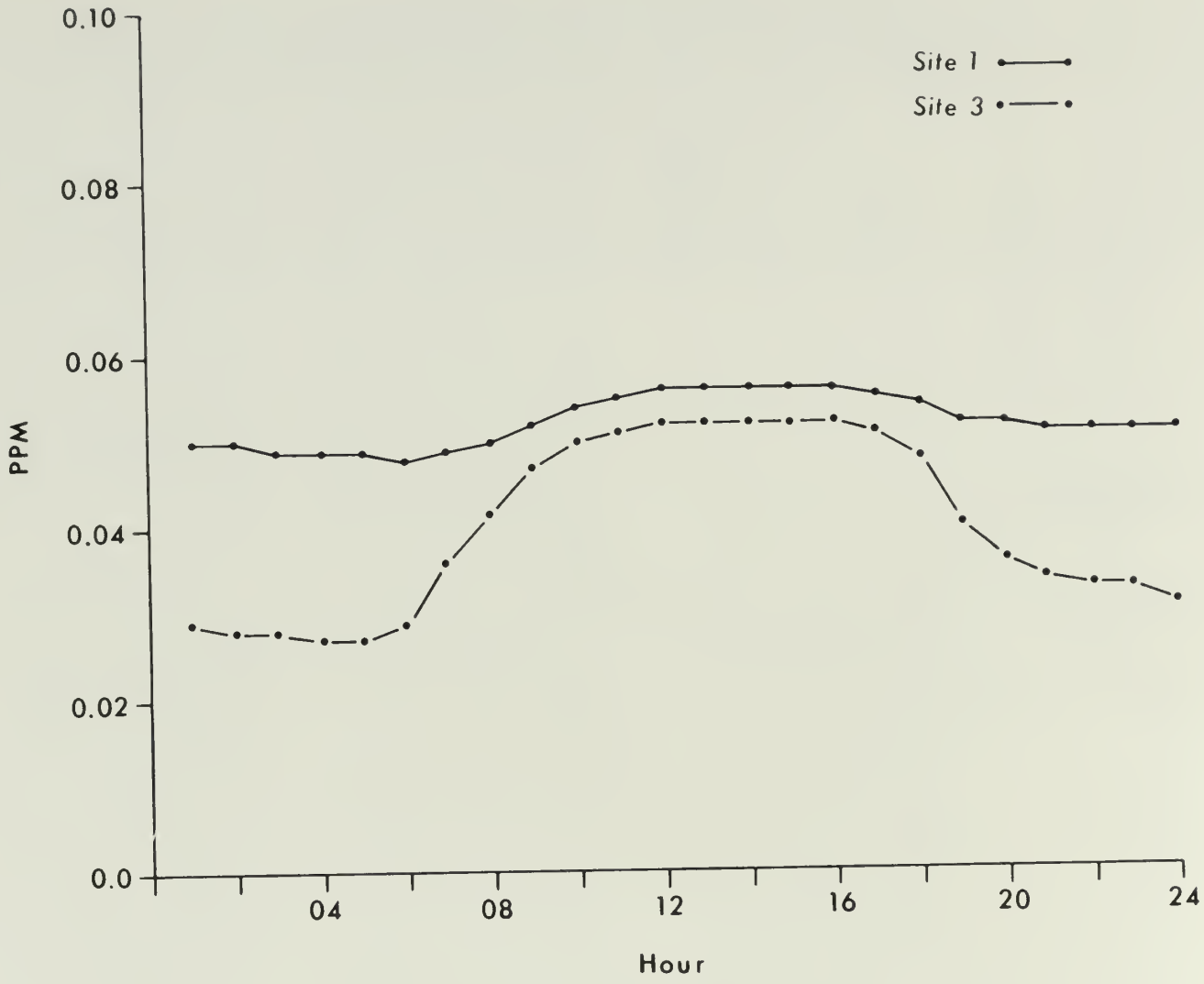

Figure 2-2. Diurnal Variation of Mean Hourly Ozone Concentrations at Sites 1 and 3, Spring (Mar-May 1980), Tract C-a

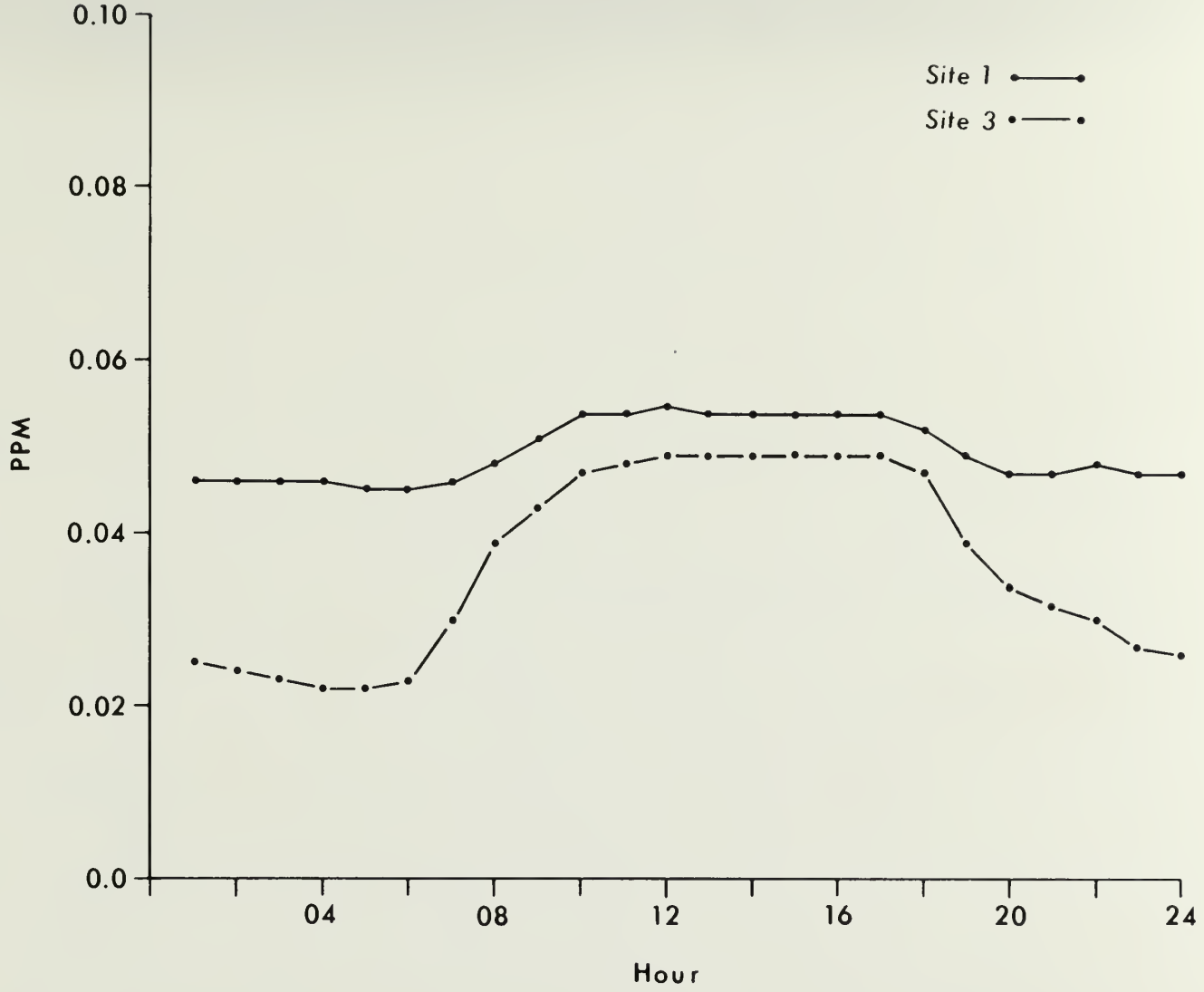

Figure 2-3. Diurnal Variation of Mean Hourly Ozone Concentrations at Sites 1 and 3, Summer (June-Aug 1980), Tract C-a

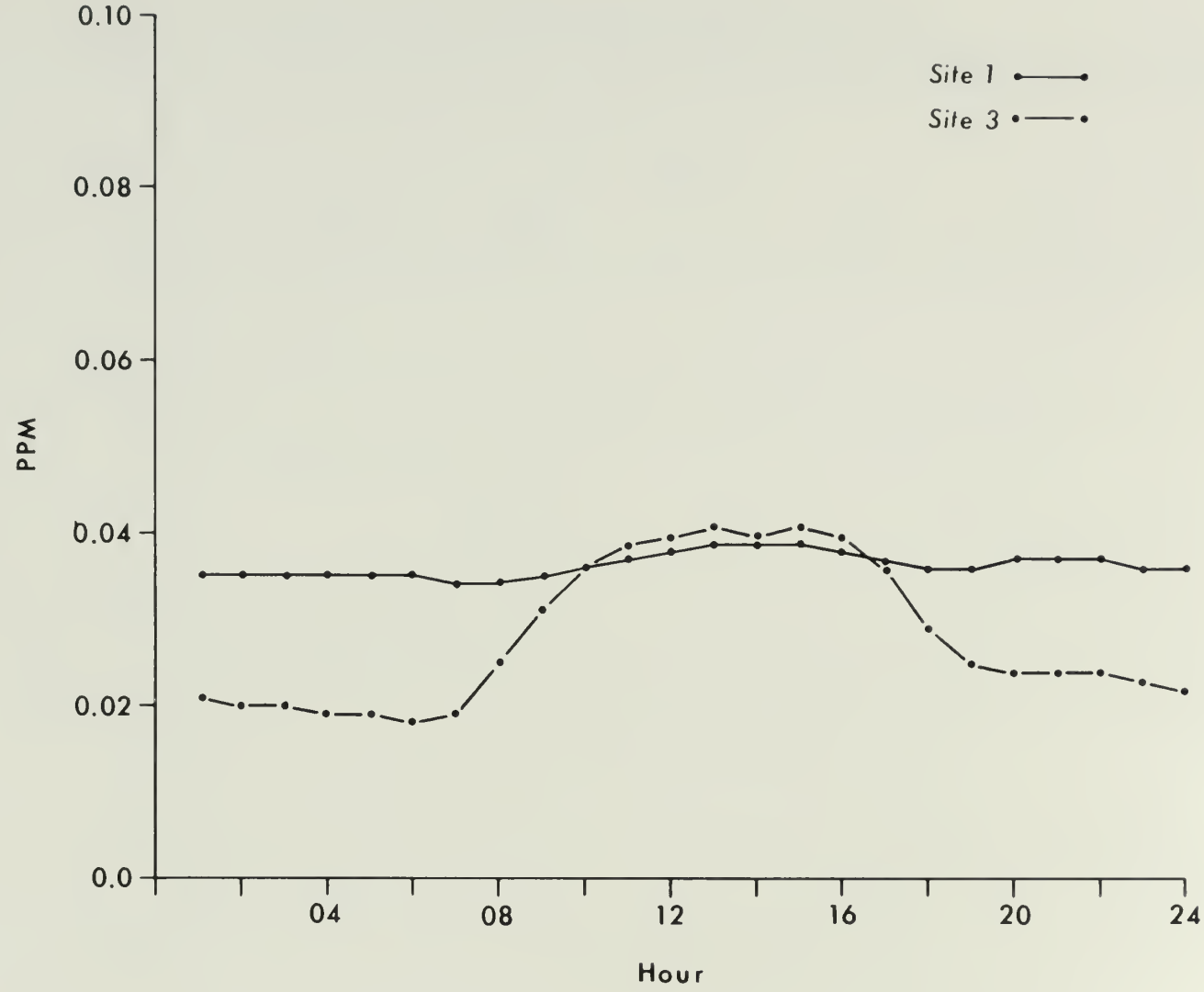

Figure 2-4. Diurnal Variation of Mean Hourly Ozone Concentrations at Sites 1 and 3, Fall (Sept-Nov 1980), Tract C-a

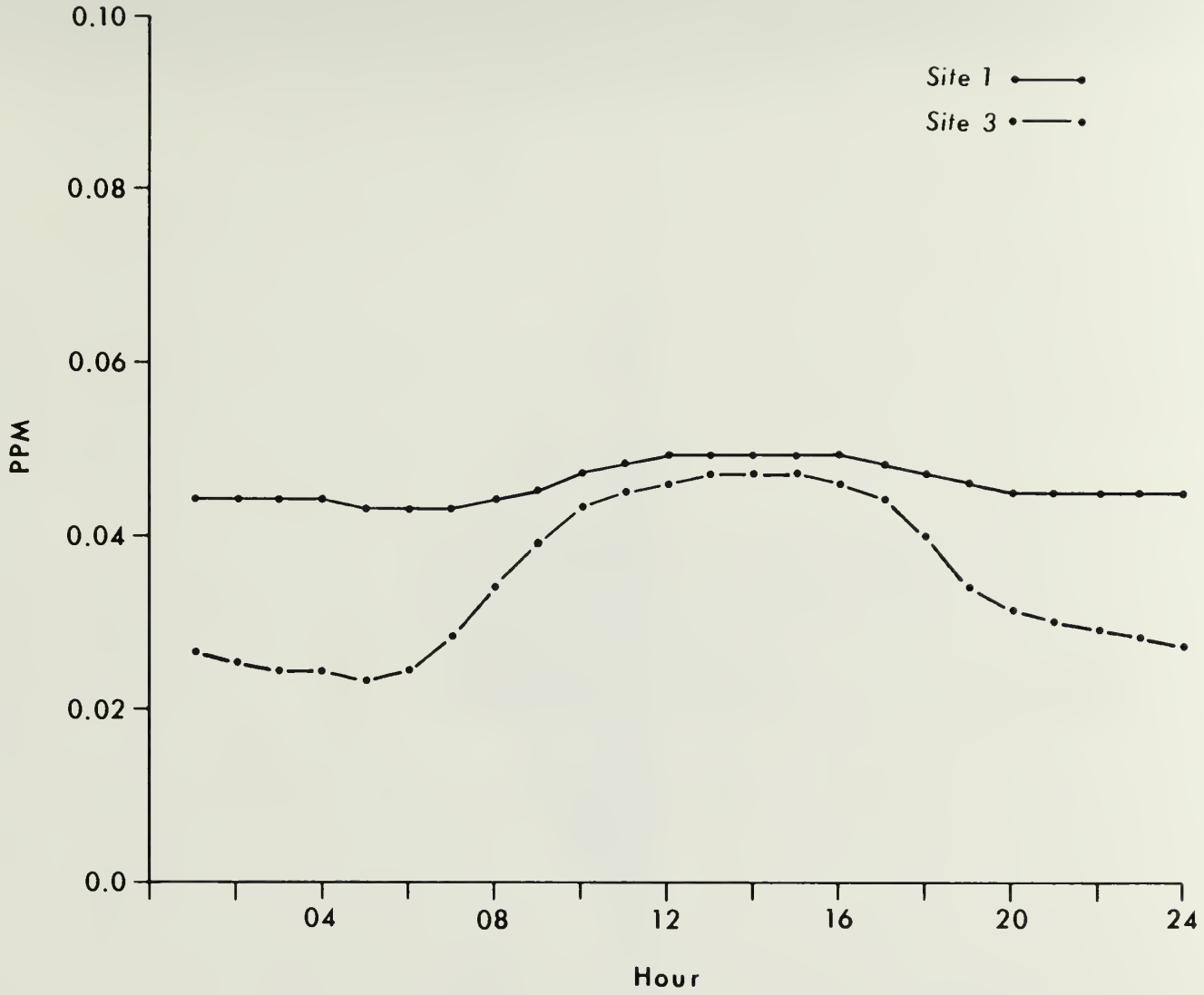

Figure 2-5. Diurnal Variation of Mean Hourly Ozone Concentrations at Sites 1 and 3, Annual Average (Dec 1979-Nov 1980), Tract C-a

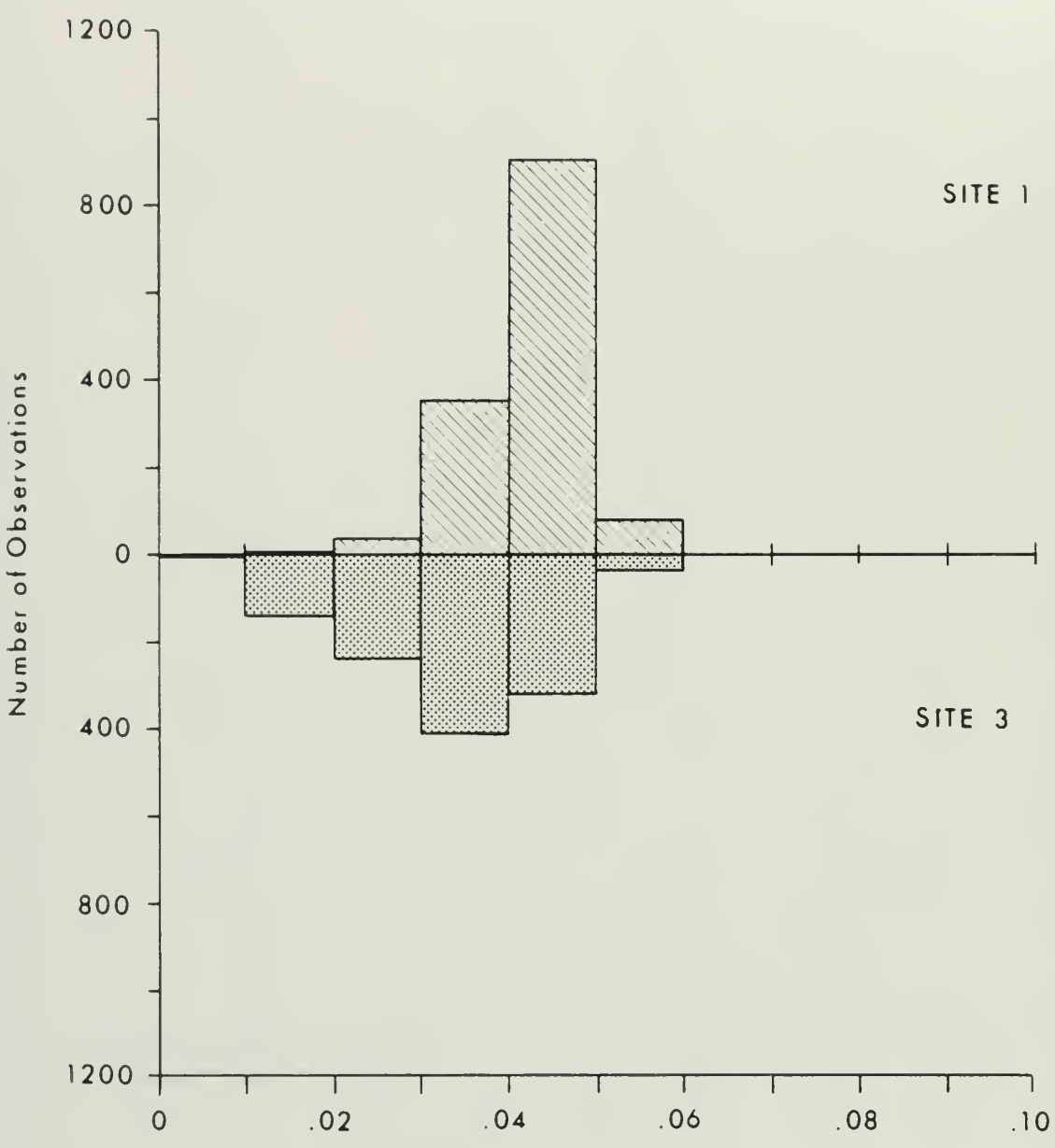

Figure 2-6. Histogram of Hourly Ozone Concentrations (ppm) at Sites 1 and 3, Winter (Dec. 1979 and Jan-Feb 1980), Tract C-a

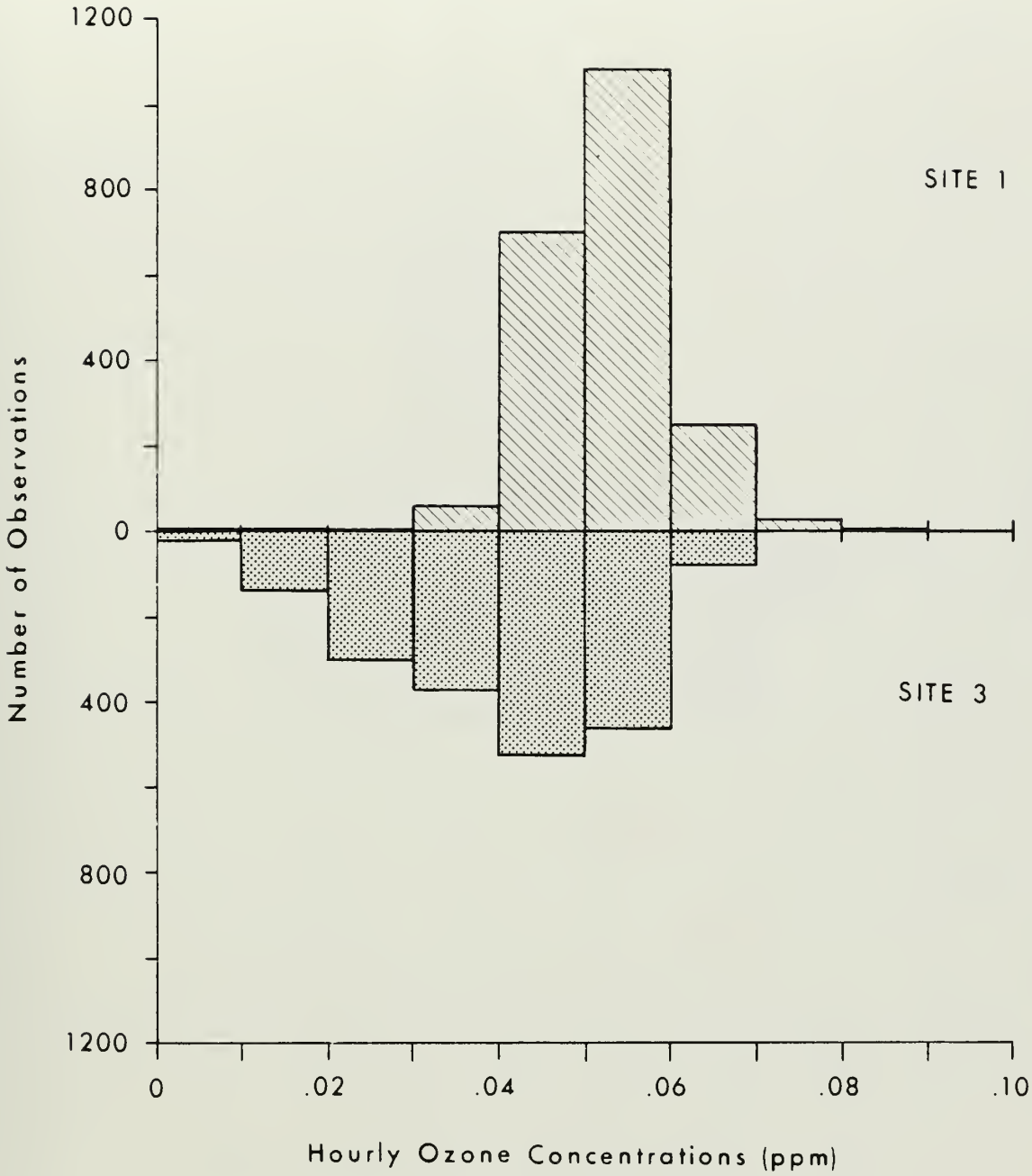

Figure 2-7. Histogram of Hourly Ozone Concentrations (ppm) at Sites 1 and 3, Spring (Mar-May 1980), Tract C-a

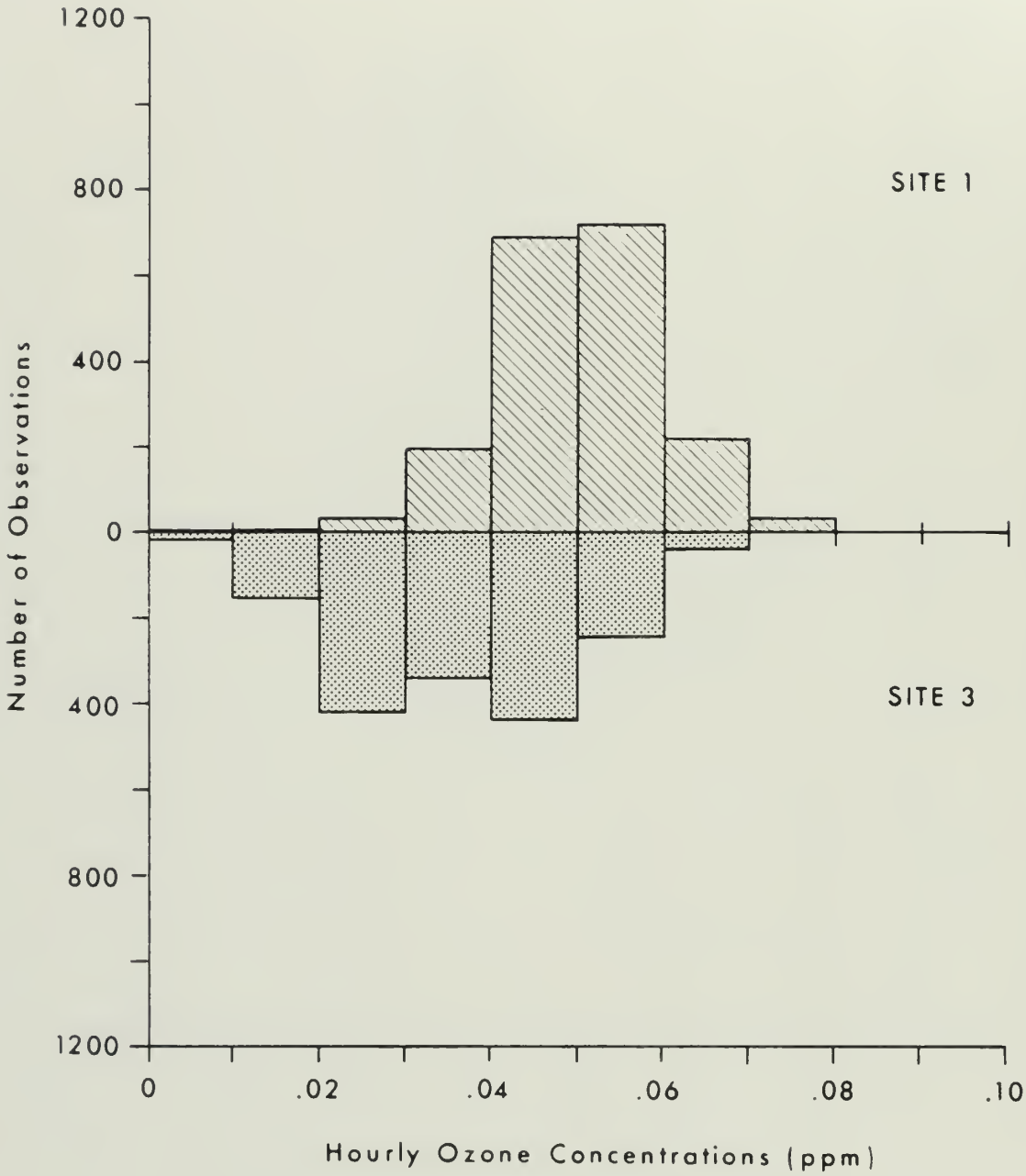

Figure 2-8. Histogram of Hourly Ozone Concentrations (ppm) at Sites 1 and 3, Summer (June-Aug 1980), Tract C-a

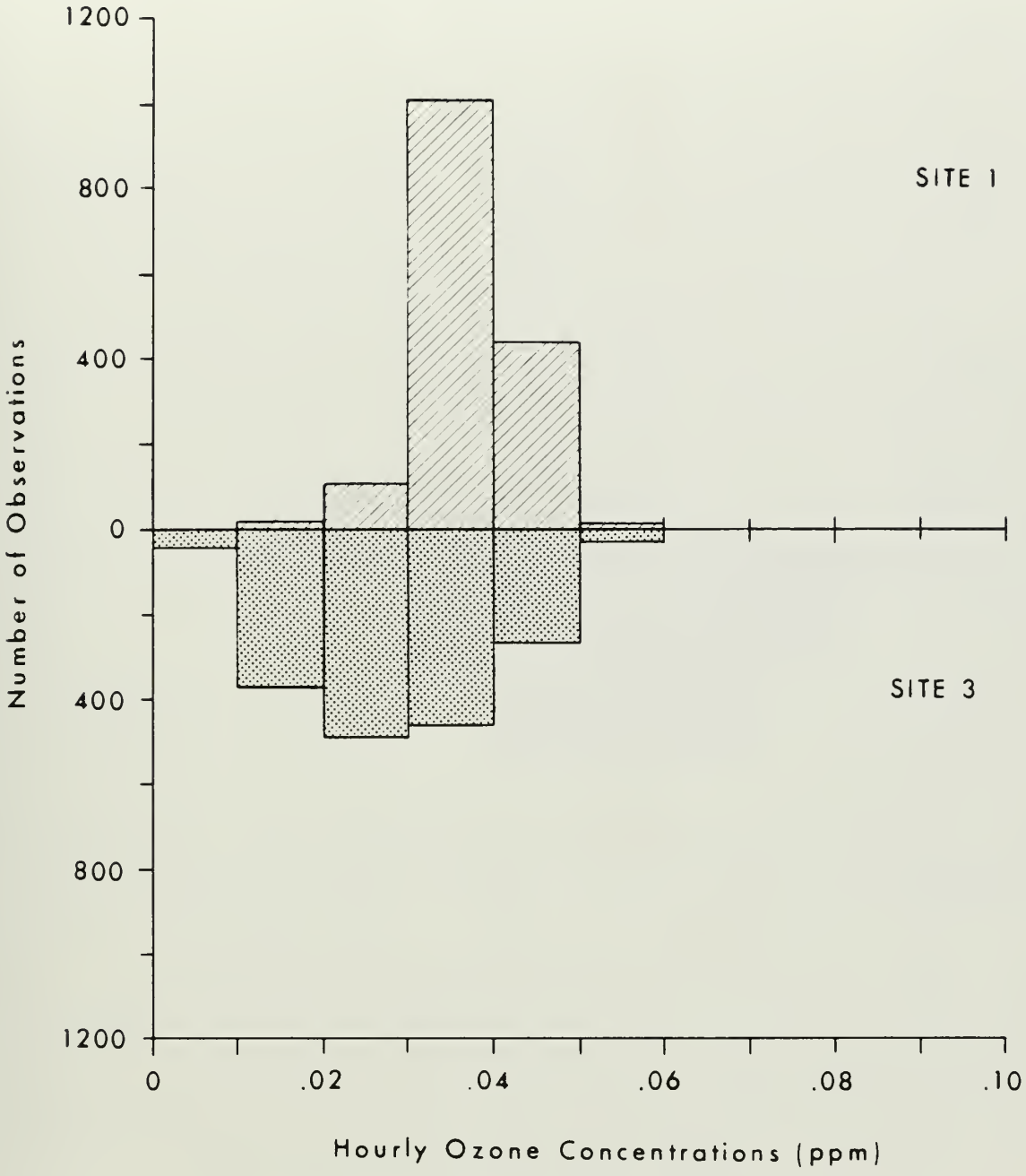

Figure 2-9. Histogram of Hourly Ozone Concentrations (ppm) at Sites 1 and 3, Fall (Sept-Nov 1980), Tract C-a

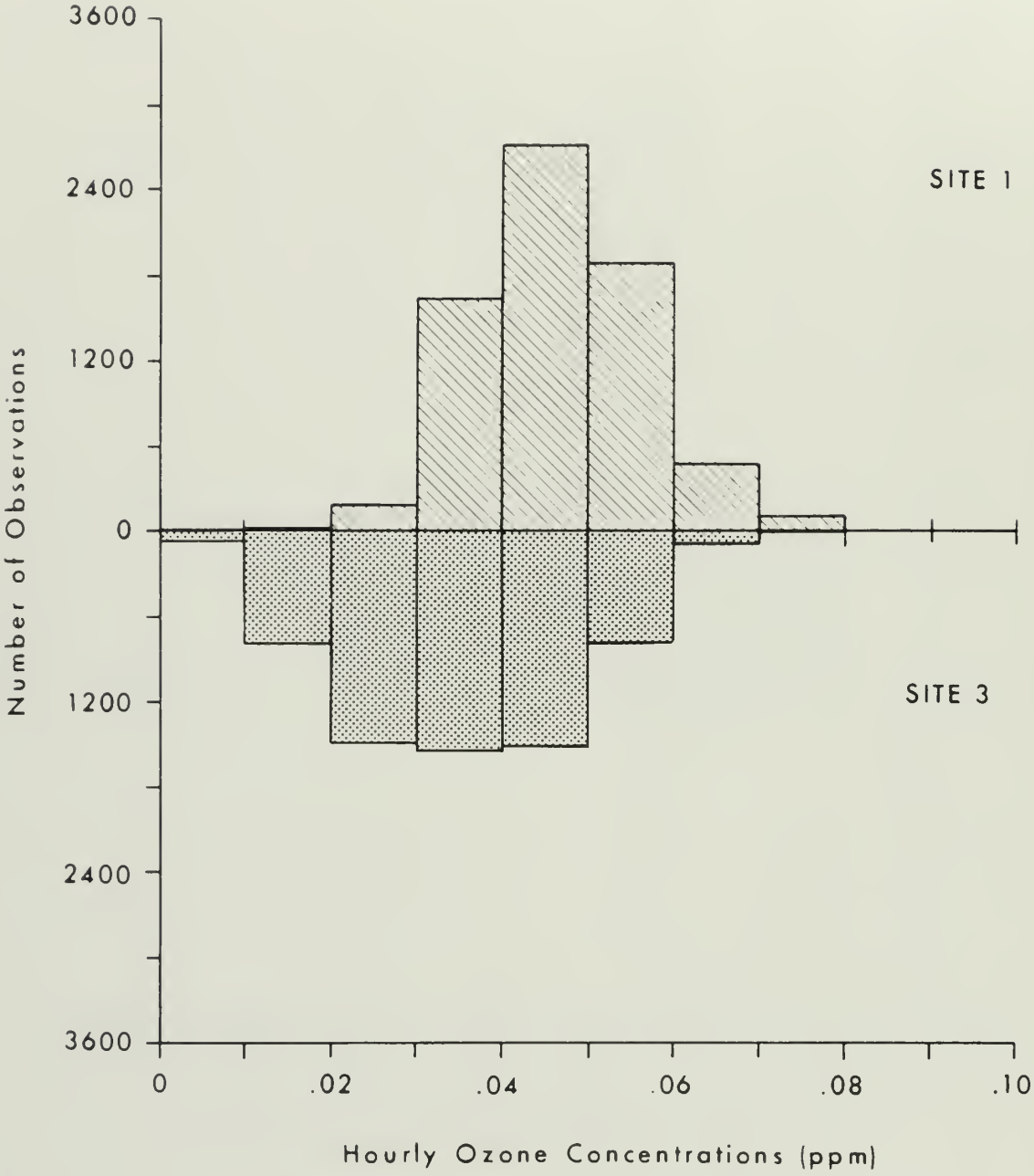

Figure 2-10. Histogram of Hourly Ozone Concentrations (ppm) at Sites 1 and 3, Dec 1979-Nov 1980, Tract C-a

The two previous year-end reports (RBOSC MDP Monitoring Reports 3 and 5) discussed this diurnal ozone cycle at Sites 1 and 3. The conclusion was that the peak daytime ozone concentrations at both sites were similar because of the efficient mixing of the boundary layer due to atmospheric turbulence. However, at night a strong surface-based inversion very often develops over the gulch in which Site 3 is located, effectively isolating Site 3 from the elevated pool of relatively ozone-rich air. This allows surface destruction reactions to reduce the ambient concentration of ozone in the gulch during the night. Since Site 1 is near the top of a hill rather than in a gulch, it is not often trapped within a strong surface inversion, and consequently does not have a mechanism to significantly reduce the ozone concentrations at night.

The other phenomenon discussed during the earlier year-end reports was the relatively high concentrations of ozone measured at such a remote site such as Tract C-a. The conclusion, based on an analysis of the site data and research done at other rural sites, was that these relatively high concentrations may be due to a number of factors, including stratospheric injection, photochemical reactions, or long-range transport. The concept of local production of ozone being an important factor has not been supported by the observed events.

F. Particulates

1. Objectives

The objectives of total suspended particulate (TSP) monitoring are to establish a natural background concentration and to monitor the effects of development of the tract.

2. Methods

The methods followed for collection of total suspended particulate data were described in RBOSC MDP Monitoring Report 4 and are not repeated herein.

3. Results and Discussion

Quarterly and annual geometric mean and maximum values of the total suspended particulate data for the current year at each of the three sites are presented in Table 2-7.

The table illustrates that a maximum concentration of 96 $\mu g/m^3$ was measured during the summer quarter at Site 3. This value is well below the National Ambient Air Quality Standard (NAAQS) for TSP of 160 $\mu g/m^3$.

One change was made in the TSP monitoring program during the current year - the Hi-Vol monitor at Site 3 was relocated approximately 150 ft. west (upvalley) of the original location. The monitor was moved in order to reduce any possible influence of a dirt access road passing within 20 ft. of the monitor on the TSP data. This road has had an increasing amount of traffic (although it is still very light), so there was some concern that the data were being biased due to fugitive dust emissions, particularly during the dry summer. To determine the effect of the move, two Hi-Vols were operated simultaneously for five months, one in the original location (now designated at Site 3C) and one in the new location.

A detailed analysis of the data collected by these two monitors is presented in a later section. However, a preliminary review based on the quarterly geometric means and maximum concentrations at Sites 3 and 3C (Table 2-7) does not indicate major differences between the two sites.

The highest quarterly geometric means and 24-hour particulate concentrations occurred during the summer. The lowest values occurred during the winter, when there was a semi-permanent snowcover on the tract.

For comparison, the quarterly and annual geometric means and maximum particulate concentrations of earlier years are presented in Tables 2-8 through 2-10. Tables 2-7 through 2-9 show that the geometric mean annual TSP concentrations for Sites 1 and 2, which are located generally upwind of the tract development areas, have maintained relatively constant values during the MDP. The mean TSP concentrations have ranged only between 11 to 14 $\mu g/m^3$. These means are slightly

Table 2-7. Quarterly and Annual Geometric Means and Maximum Values of 24-hour Average Total Suspended Particulate Concentrations from December 1979 to November 1980 ($\mu g/m^3$) on Tract C-a

	Site 1	Site 2	Site 3	Site 3C
Tenth Quarter MDP (December 1979 - February 1980)				
Geometric Mean	6	5	7	--
Maximum	15	20	29	--
Eleventh Quarter MDP (March - May 1980)				
Geometric Mean	11	12	14	--
Maximum	36	42	51	--
Twelfth Quarter MDP (June - August 1980)				
Geometric Mean	29	21	43	39[1/]
Maximum	61	51	96	105[1/]
Thirteenth Quarter MDP (September - November 1980)				
Geometric Mean	16	15	24	25
Maximum	56	61	76	69
Annual (December 1979 - November 1980)				
Geometric Mean	13	12	18	--
Maximum	61	61	96	--

[1/] Based on a two-month data set

Table 2-8. Quarterly and Annual Geometric Means and Maximum Values of 24-hour Average Total Suspended Particulate Concentrations from December 1978 to November 1979 ($\mu g/m^3$) on Tract C-a

	Site 1	Site 2	Site 3
Sixth Quarter MDP (December 1978 - February 1979)			
Geometric Mean	4	4	8
Maximum	8	12	65
Seventh Quarter MDP (March - May 1979)			
Geometric Mean	8	9	19
Maximum	34	33	94
Eighth Quarter MDP (June - August 1979)			
Geometric Mean	18	24	46
Maximum	53	52	192
Ninth Quarter MDP (September - November 1979)			
Geometric Mean	22	15	27
Maximum	303	87	145
Annual (December 1978 - November 1979)			
Geometric Mean	11	12	21
Maximum	303	87	192

Table 2-9. Quarterly and Annual Geometric Means and Maximum Values of 24-hour Average Total Suspended Particulate Concentrations from December 1977 to November 1978 ($\mu g/m^3$) on Tract C-a

	Site 1	Site 2	Site 3
Second Quarter MDP (December 1977 - February 1978)			
Geometric Mean	4	3	5
Maximum	9	5	33
Third Quarter MDP (March - May 1978)			
Geometric Mean	12	11	16
Maximum	38	39	54
Fourth Quarter MDP (June 1978 - August 1978)			
Geometric Mean	22	22	77
Maximum	59	60	160
Fifth Quarter MDP (September - November 1978)			
Geometric Mean	17	15	39
Maximum	51	34	155
Annual (December 1977 - November 1978)			
Geometric Mean	14	13	26
Maximum	59	60	160

Table 2-10. Quarterly and Annual Geometric Means and Maximum Values of 24-Hour Average Total Suspended Particulate Concentrations for the Baseline period (February 1975 to January 1977) ($\mu g/m^3$) on Tract C-a

	Site 1	Site 2	Site 3
February 1975			
Geometric Mean	--	3	5
Maximum	--	10	12
Spring 1975 (March-May)			
Geometric Mean	29	11	23
Maximum	95	84	163
Summer 1975 (June-August)			
Geometric Mean	22	15	47
Maximum	211	95	247
Fall 1975 (September-November)			
Geometric Mean	6	16	18
Maximum	52	102	137
Winter 1975-76 (December-February)			
Geometric Mean	2	2	4
Maximum	10	11	14
Spring 1976 (March-May)			
Geometric Mean	11	11	11
Maximum	80	51	130
Summer 1976 (June-August)			
Geometric Mean	22	22	27
Maximum	81	57	105
Fall 1976 (September-November)			
Geometric Mean	12	15	35
Maximum	53	46	281
Winter 1976-77 (December-January)			
Geometric Mean	5	6	5
Maximum	18	57	59

Table 2-10 (Continued)

	Site 1	Site 2	Site 3
1975-76 Annual			
Geometric Mean	9	9	18
Maximum	211	102	247
1976-77 Annual			
Geometric Mean	8	9	12
Maximum	81	57	281

higher than those for the baseline period (Table 2-10), when mean concentration ranged from 8 to 9 $\mu g/m^3$.

The geometric mean annual TSP concentrations at Site 3, located generally downwind of the tract development areas, have been considerably higher than the other sites during the MDP, ranging from 26 $\mu g/m^3$ in 1978 to 18 $\mu g/m^3$ in 1980. This contrasts with the mean annual TSP concentrations during the two baseline years of 12 and 18 $\mu g/m^3$.

The tables illustrate that there is an interesting seasonal difference in the ratio of monitored TSP concentrations between Site 3 and the other two sites: during the winter and the spring seasons, the geometric mean TSP concentrations at all three sites are very similar, while during the summer, the Site 3 mean is approximately double that of Sites 1 and 2. This is reasonable, since the winter snowcover should reduce the localized impacts on individual sites. High fugitive dust emissions during the dry summer from tract development or other activities, on the other hand, should have the greatest impact at Site 3.

Tables 2-7 through 2-9 show that the geometric mean annual TSP concentrations at Site 3 have declined steadily from 26 to 18 $\mu g/m^3$ between 1978 and 1980, as pointed out above. This decline in TSP concentrations at Site 3 over the three years is most apparent during the summer quarter: geometric mean TSP concentrations for the summer were 77 $\mu g/m^3$ in 1978, 46 $\mu g/m^3$ in 1979, and 43 $\mu g/m^3$ in 1980. The major decrease in TSP concentrations in the summer quarter occurred between 1978 and 1979, which can be at least partially attributed to the paving of the main tract access road (which passes within 100 yards of Site 3) during the the 1978 summer quarter.

Neither the primary nor the secondary National Ambient Air Quality Standard for TSP was exceeded during the current year. The highest concentration recorded-96 $\mu g/m^3$-was monitored at Site 3, except for Site 3C, which measured a slightly higher value of 105 $\mu g/m^3$.

The annual cumulative frequency distributions of the TSP concentrations at each of the three sites are presented in Figure 2-11. The distributions for Sites 1 and 2 are similar. The figure shows that the 50 percent probability point for the TSP concentrations are 16 $\mu g/m^3$ for Site 1, ^{12} $\mu g/m^3$ for Site 2, and 13

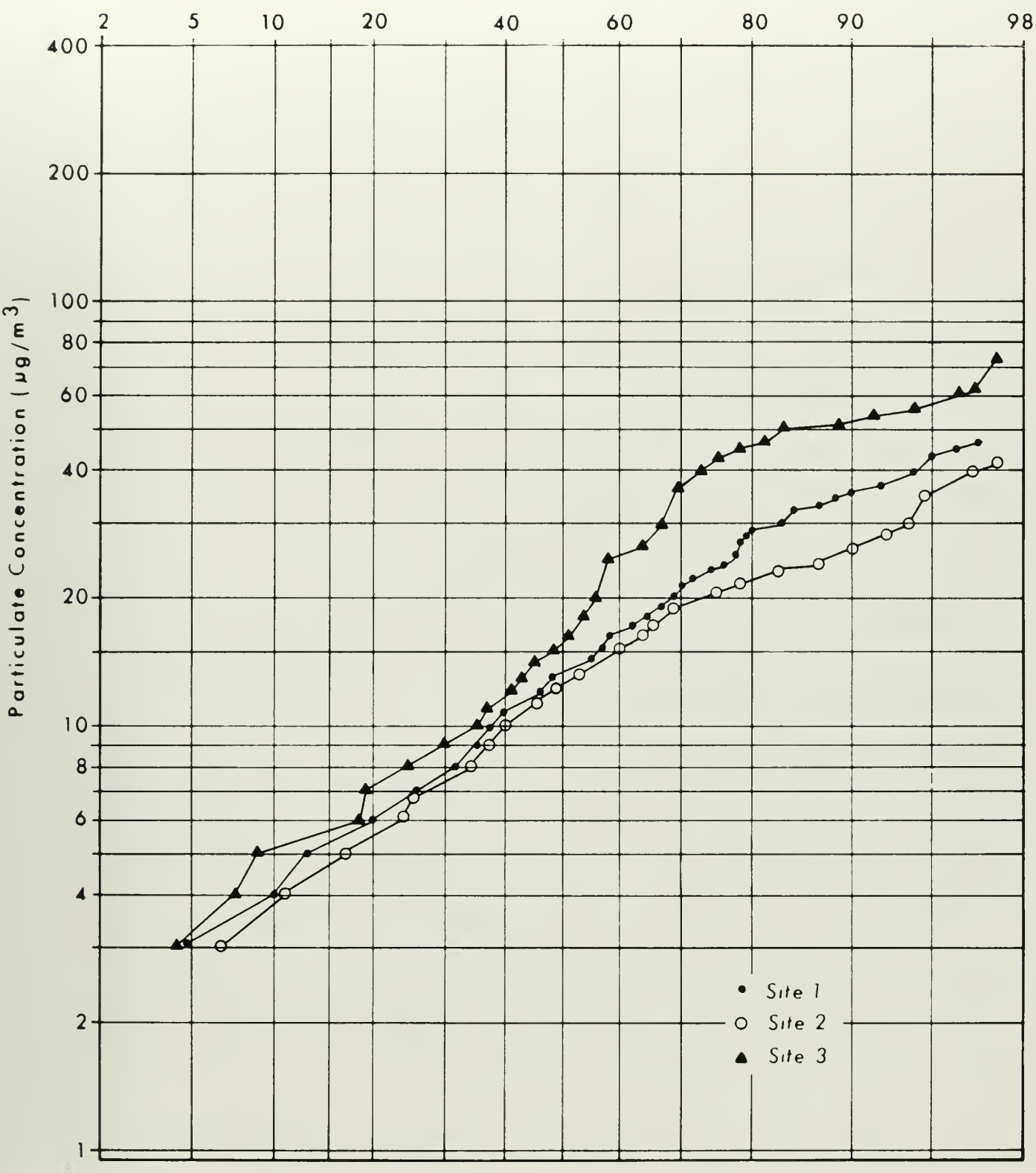

Figure 2-11. Cumulative Frequency Distributions of Total Suspended Particulate Data From the Three Tract C-a Monitoring Sites, December 1979—November 1980

$\mu g/m^3$ for Site 3. These compare reasonably well with values obtained in 1978-79 of 10 $\mu g/m^3$, 13 $\mu g/m^3$, and 20 $\mu g/m^3$ for the same sites, respectively. The 50 percent probability concentrations obtained for the baseline period (RBOSP 1976), 10 $\mu g/m^3$ for Site 1, 12 $\mu g/m^3$ for Site 2, and 22 $\mu g/m^3$ for Site 3, also agree well with both of these data sets from the MDP. The data from 1977-78 cannot easily be compared because the sampling frequency data capture efficiency was much lower compared to the other years of data collection.

a. Correlation analysis - One of the reasons for conducting this analysis is to evaluate the factors affecting the seasonal differences in the particulate concentrations. As discussed above, it is quite possible that a variety of physical processes and mechanisms may affect the data during different times of the year. In particular, during winter, the semi-permanent snowcover should reduce the impacts of localized particulate sources (i.e., the main tract access road near Site 3, or the pipeline right of way adjacent to Site 1), such that the sites are influenced more by general regional sources. Thus, particulate concentrations among sites might be expected to be more highly correlated during the winter than during the summer. Figures 2-12 through 2-14, which present the separate cumulative distributions for the winter and summer seasons, indicate that at each site the cumulative distributions can be subdivided into the two seasons with minimum overlap.

Table 2-11 presents the correlations of the particulate concentrations among the three sites for each of the four years of record. The correlations are given for the entire data year, the summer season (defined for purposes of this analysis as the period within each data year during which snowcover was absent), and the winter season (defined for the purpose of this analysis as the period within each data year during which snowcover was present). Because of the year-to-year variability in meteorological factors, the length of the two seasons varied considerably. Based on snow depth and precipitation records, the summer season for each year was determined to be:

Baseline year one (2/75-1/76)	April 11 - October 23, 1975
Baseline year two (2/76-1/77)	March 30 - December 1, 1976
MDP year one (12/77-11/78)	March 25 - November 8, 1978
MDP year two (12/78-11/79)	April 14 - October 28, 1979
MDP year three (12/79-11/80)	April 13 - October 13, 1980

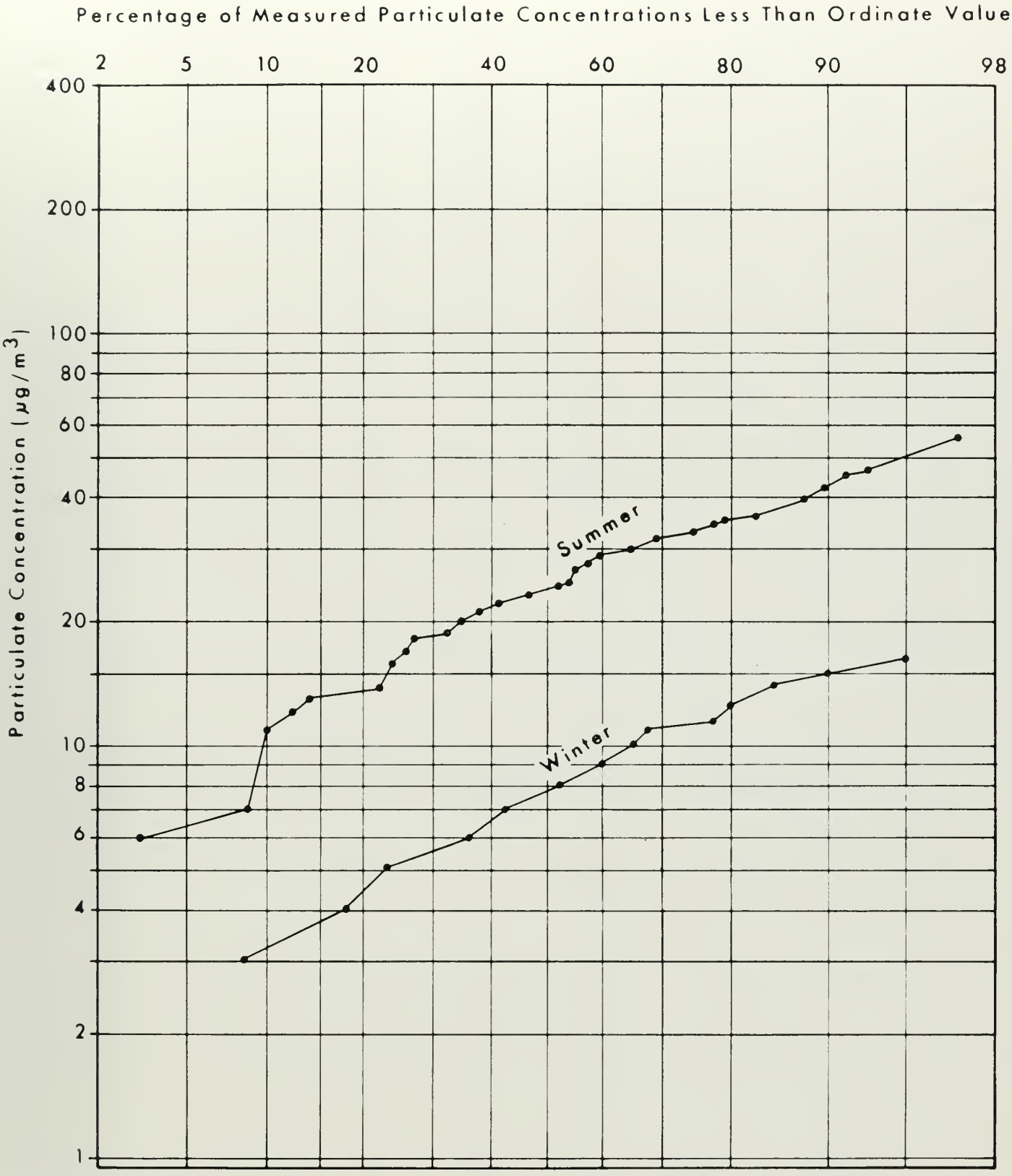

Figure 2-12. Cumulative Frequency Distributions of Total Suspended Particulate Data from Site 1 During the 1979-80 Summer and Winter Season, Tract C-a

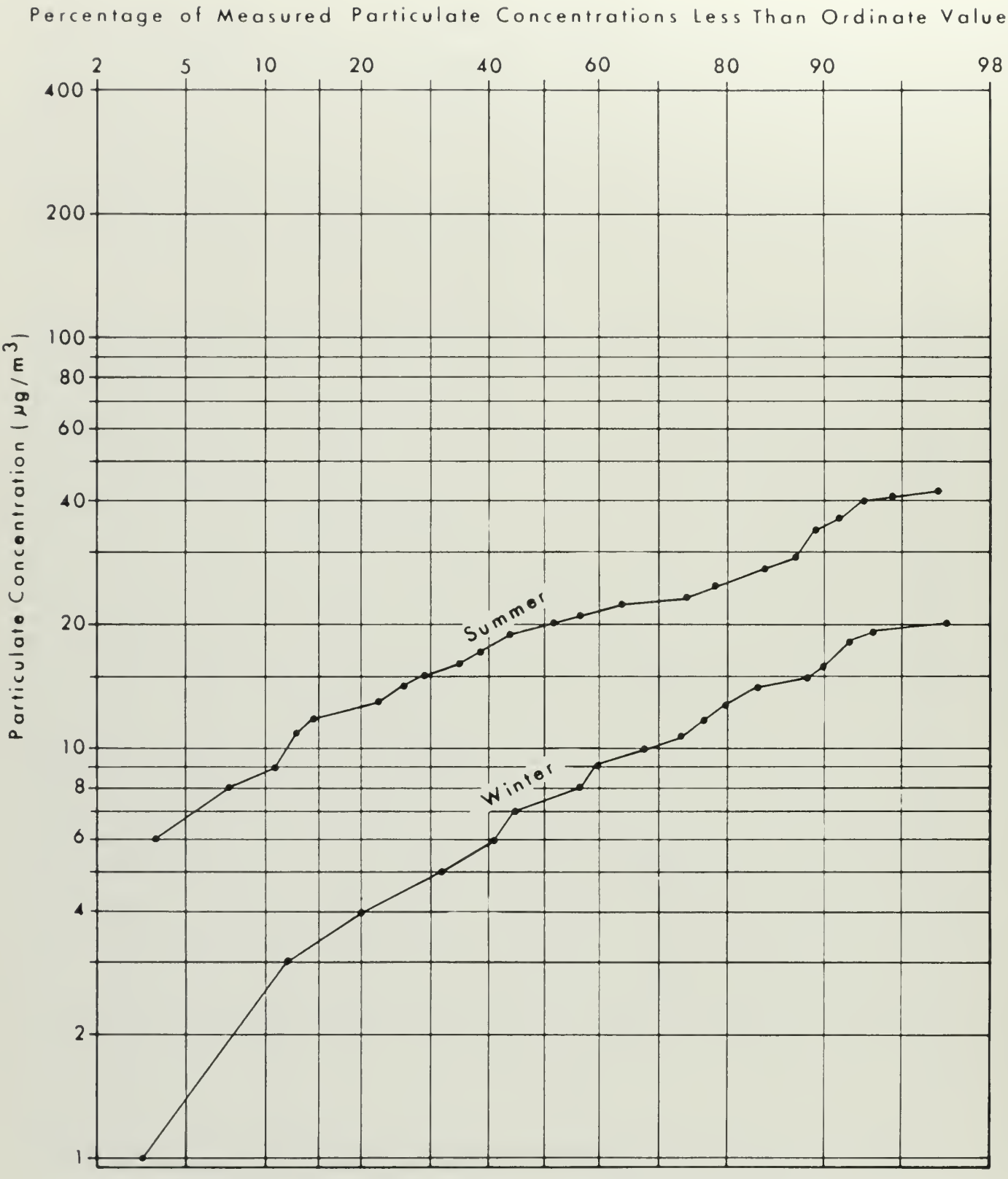

Figure 2-13. Cumulative Frequency Distributions of Total Suspended Particulate Data From Site 2 During the 1979-80 Summer and Winter Season Tract C-a

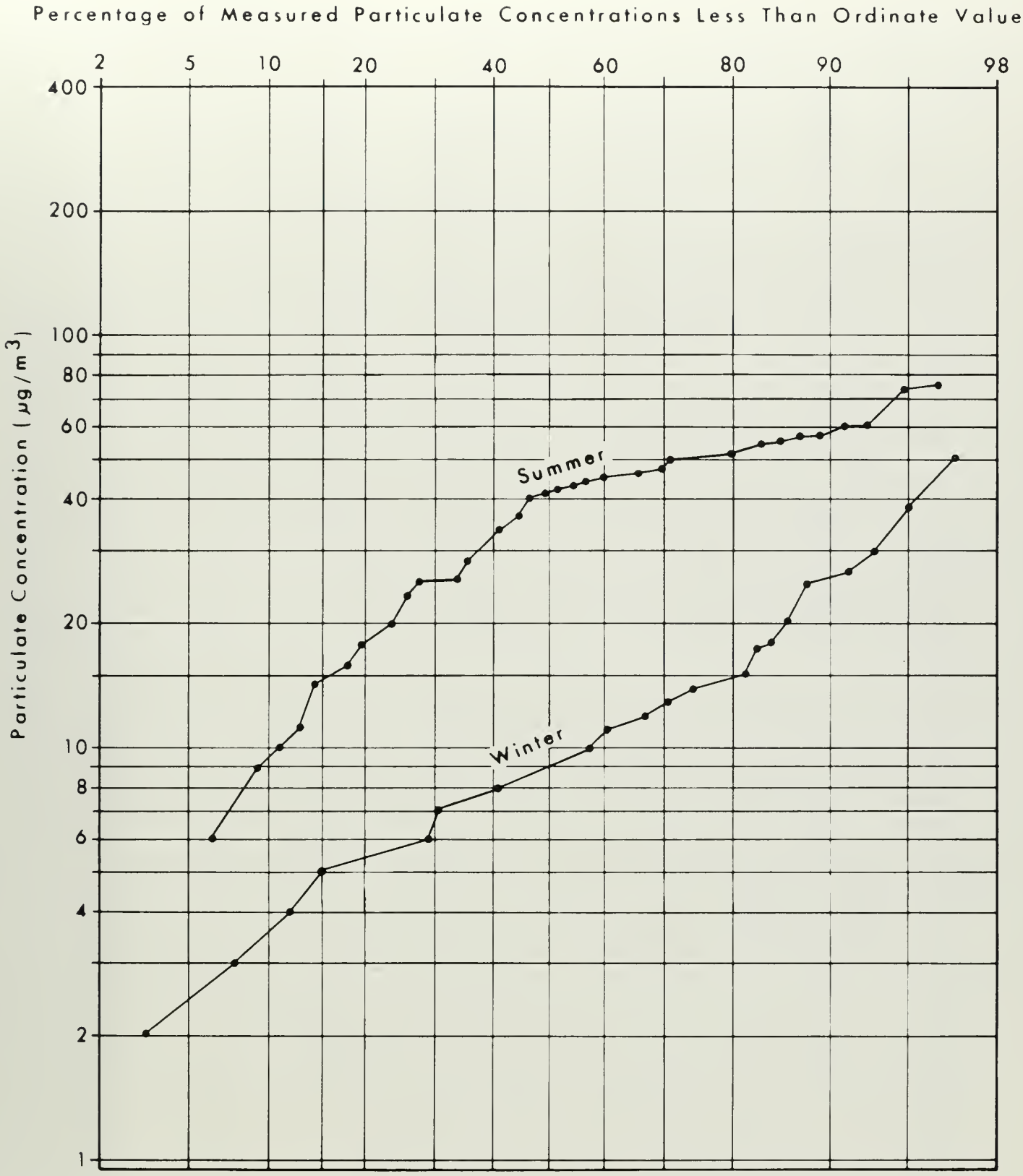

Figure 2-14. Cumulative Frequency Distributions of Total Suspended Particulate Data from Site 3 During the 1979-80 Summer and Winter Seasons, Tract C-a

Table 2-11. Correlation Coefficients (r), Coefficients of Determination (r^2), and Sample Number (N) for the 24-hour Average Total Suspended Particulate Concentrations at Sites 1, 2, and 3, Tract C-a

	Baseline						Modular Development Phase								
	(2/75 - 1/76)			(2/76 - 1/77)			(12/77 - 11/78)			(12/78 - 11/79)			(12/79 - 11/80)		
Correlation	r	r^2	N	r	r^2	N	r	r^2	N	r	r^2	N	r	r^2	N
For Total Year															
Sites 1 vs 2	0.53	0.28	91	0.63	0.40	91		NA[1]		0.84	0.70	103	0.87	0.75	114
Sites 1 vs 3	0.31	0.10	89	0.49	0.24	114				0.62	0.38	107	0.84	0.70	112
Sites 2 vs 3	0.56	0.32	105	0.47	0.22	72				0.69	0.48	100	0.77	0.60	109
For Summer Only															
Sites 1 vs 2	0.43	0.19	59	0.57	0.33	53	0.81	0.65	50	0.78	0.61	58	0.78	0.61	54
Sites 1 vs 3	0.14[3]	0.02	57	0.43	0.18	86	0.44	0.19	47	0.45	0.21	57	0.77	0.60	54
Sites 2 vs 3	0.40	0.16	63	0.36	0.13	42	0.44	0.19	48	0.51	0.26	55	0.63	0.40	52
For Winter Only															
Sites 1 vs 2	0.17[3]	0.03	32	0.36	0.13	38		NA[2]		0.84	0.71	45	0.84	0.71	60
Sites 1 vs 3	0.16[3]	0.03	32	0.23[3]	0.05	28				0.60	0.36	50	0.57	0.32	58
Sites 2 vs 3	0.73	0.53	42	0.47	0.22	30				0.76	0.57	45	0.61	0.37	57

[1] 1977-1978 annual correlations not presented due to inadequate data set from winter season

[2] An average of only 4 paired samples exist for correlative purposes during the winter season of 1977-1978

[3] These correlations are not significantly different than zero at $\alpha = 0.05$

The period before and after the summer season of each year was taken to be the winter season.

No correlations are given in Table 2-11 for either the winter season or the entire year of the first MDP year, because an average of only four paired samples exist for correlative purposes during the winter season. This was caused by equipment problems associated with the start-up of the MDP environmental program and to a once-per-six-day sampling schedule in which each site monitor was run on alternate days until late March, 1978.

The highest correlation given in Table 2-11 (0.87) for the 1979-80 data set is between Site 1 and 2 for the total year. This is reasonable, since higher correlations are expected between these two control sites (both sites are generally upwind of the tract) than between Sites 1 and 3 or Sites 2 and 3 (Site 3 is the treatment site located in a gulch that drains much of the tract). However, it is somewhat surprising to find correlations of the yearly data set nearly as high between Sites 1 and 3 (0.84) and between Sites 2 and 3 (0.77). These correlations are clearly higher than their respective values during 1978-79 (0.62 and 0.69).

Caution must be used in interpreting correlations, particularly since they may imply, but do not establish, cause and effect relationships. Nevertheless, it appears that at least on an annual basis, the monitors were not as strongly influenced individually by localized sources of fugitive dust (i.e., activity in the middle of the tract, local roads, or pipeline construction) as by regional sources of particulates. Evidence of this can be seen in the decreasing difference between the annual geometric means of Site 3 and Site 2 (13 $\mu g/m^3$ in 1977-78, 9 $\mu g/m^3$ in 1978-79, and 6 $\mu g/m^3$ in 1979-80), as well as the year-to-year increase in correlations between the sites.

This trend to stronger correlations between the sites during 1979-80 as compared to 1978-79 also occurs in the summer data set, but does not occur in the winter data set. There are two possible explanations of why there was no improvement in correlations during the winter: 1) particulate levels are generally quite low in the area during the winter, sometimes near the limit of detectability of the monitors, thereby reducing the accuracy of the measurements; and 2) the

construction of the Lurgi access road in November 1980 may have caused a localized, temporary impact on the nearby Site 3, which did not occur at the other two sites, thus preventing the correlations from being stronger (this question will be taken up later in the next section).

The major improvements in the correlations from 1978-79 to 1979-80 were between Sites 1 and 3 and between Sites 2 and 3, both for the summer and for the annual data set. One cause for these improvements may have been the improvements in the representativeness of Site 3 as a Hi-Vol monitoring location for measuring the impacts of activity, i.e., the paving of the main tract access road which passes through Corral Gulch within 100 yards of Site 3, and the movement of the site 150 ft west of its original location.

b. Comparison of Site 3 and Site 3C - As discussed earlier, two Hi-Vol monitors were run simultaneously for five months (July-November) at Site 3 in order to determine if there was any effect of moving the monitor 150 ft from a lightly traveled, but very dusty (in the summer) access road. Table 2-7 illustrates that Sites 3 and Site 3C (the original site) both have similar maximum concentrations (96 $\mu g/m^3$ vs. 105 $\mu g/m^3$, respectively) and similar quarterly geometric mean concentrations (24 $\mu g/m^3$ vs. 25 $\mu g/m^3$, respectively, for the Fall quarter).

The correlation between the two data sets for the entire five-month period is 0.93, indicating a high degree of similarity between the data sets. In addition, a t-test was run to test the following hypothesis:

H_o: The differences between the two TSP data sets are not significantly different than zero.

The mean difference in TSP concentrations, 0.9 $\mu g/m^3$, is not significantly different than zero, even at the 10 percent significance level.

Since the data sets cannot be proven to be significantly different, no correction to the earlier TSP data sets is either necessary or warranted. Nevertheless, the new location will continue to be used to ensure that future data will not be biased by increased use of the dirt access road.

c. Regression Analyses - The objective of these analyses is to investigate the predictive ability of a number of meteorological and site activity variables on the concentration of particulates at each of the three monitoring sites. In addition, the relative importance of these variables in explaining the TSP concentrations can be examined. For the purposes of this analysis, a set of variables has been used to establish the meteorological conditions and site activity on each sampling day. These variables were defined as:

PRECIP - precipitation on the sampling day (hundredths of an inch)

DSPREP - number of days since significant precipitation occurred (defined as 0.10 inch)

TEMP - average daily temperature (C)

WS - average daily wind speed (mph)

MAXWS - maximum hourly wind speed (mph)

WSHR12 - number of hours that average wind speed exceeded 12 mph

DEWPT - average daily dewpoint (C)

MANPOWER - number of workers on tract

MUCK - number of trips per day by 35-ton truck to dump muck from the mine (indicator of both mine and surface activity)

BDPS - number of pieces of earth-moving machinery used in constructing new scrubber blowdown ponds

LURGI - number of pieces of earth-moving machinery used in constructing the Lurgi access road.

All of the meteorological variables used in the regression analysis were site specific, with the exception of dewpoint (measured only at Site 1). That is, they were collected at the same site as the TSP concentrations. The regressions were run for the total year, the summer season, and the winter season, similar to the approach used in the correlation analysis.

1. Multiple Regression - Table 2-12 gives the coefficient of determination (r^2) resulting from the multiple regression analysis. The results show that 67 percent of the variation on a yearly basis of the particulate concentrations at Site 1 can be explained by the combination of meteorological and site activity variables. Similarly, 61 percent of the variation at Site 2 and 73 percent of the variation at Site 3 can be explained by the meteorological and site activity variables.

For Sites 1 and 3 the regressions for the individual seasons were lower than the regressions of the total yearly data set, with r^2 values averaging 0.5 at Site 1 and 0.6 at Site 3. This may be partly due to the larger sample size for the yearly data set (which helps to reduce the impact of any inconsistent data points), and partly due to improved correlation by parameters that have an annual cycle similar to that of TSP concentrations, such as temperature. At Site 2, the r^2 was higher (0.73) for the winter data set than for the annual data set. Part of the inconsistency in the seasonal results at Site 2 (in comparison with Sites 1 and 3) may be due to a smaller data set available at that site for regression during each individual season at the site. (This is due to somewhat lower data recovery at Site 2, and to the computer program, which deletes a sampling day if any regression parameter on that day is missing).

The results of the regression analysis applied to the annual data set have been remarkably consistent over the past three years. This is especially true since some of the site activity and meteorological parameters used in the regression have been changed in an attempt to find a better fit. Regardless of the parameters chosen, the results indicate that about one-third of the variation in the TSP concentration at each site still remains unexplained.

2. Stepwise Multiple Regression - A further use of regression analysis is a technique known as stepwise multiple regression, in which a

Table 2-12. The Coefficient of Determination (r^2) Values and Number of Samples (in Parentheses) Resulting from the Multiple Regression of the Meteorological and Site Activity Variables on the Total Suspended Particulate Concentrations at each Site on Tract C-a During December 1979 - November 1980

	r^2		
	Site 1	Site 2	Site 3
Total Year	0.67 (98)	0.61 (64)	0.73 (91)
Summer	0.56 (48)	0.43 (34)	0.61 (45)
Winter	0.46 (50)	0.73 (30)	0.58 (46)

regression algorithm selects the meteorological and site activity variables by their importance as predictors of the dependent variable (particulate concentration). The end result is a ranking by importance of the eleven independent variables (as given earlier), regardless of their classification as a meteorological or site activity variable. Tables 2-13 through 2-15 present the results of the respective stepwise regressions for Sites 1, 2 and 3. The regressions were run against three data sets from the current year: the summer season, the winter season, and the entire year. The same predictors used in the multiple regression analysis were used in this analysis. For each step in each of the regressions, the tables list the predictor entered, the coefficient of determination (r^2) for the regression containing the predictors entered thus far, the increase in r^2 from the preceeding step, and the percent increase in r^2 with the added predictor. Predictors added to each regression are included in the table up to the step where the next predictor's significance probability exceeds $\alpha = 0.05$.

A number of conclusions can be reached from this analysis (Tables 2-13 through 2-15):

- For all three sites, the predictors meeting the significance criterion ($\alpha = 0.05$) are most successful in explaining the variation in TSP concentrations when using the data set for the entire year. As discussed above, this is probably a result of the strong annual cycle that TSP concentrations exhibit, in contrast to a widely variable and perhaps partly random variation with each season. The predictors were least successful in explaining the variation at Site 2 during the summer. This may be at least partly due to the relatively small number of sample days available for the regression analysis during the summer.

- The predictor most successful in explaining the variation in the yearly data set at each site is temperature. This one predictor had an r^2 value of better than 0.50 at each site. Of all the predictors used, it alone has an annual cycle similar to the TSP concentrations. The second most successful predictor was DSPREP (number of days since

Table 2-13. Results of Stepwise Regressions of Total Suspended Particulate Concentrations for Sites 1, 2 and 3 During the 1979-80 Year, Tract C-a

Site 1 Data (98 cases)

Step	1	2	3
Predictor	TEMP	DSPREP	MUCK
r^2	.552	.606	.633
Increase in r^2	.552	.054	.027
(α) associated with adding variable to regression	.0001	.0005	.0086

Site 2 Data (64 cases)

Step	1	2	3
Predictor	TEMP	DEWPT	WSHR12
r^2	.532	.565	.582
Increase in r^2	.532	.033	.017
(α) associated with adding variable to regression	.0001	.037	.049

Site 3 Data (91 cases)

Step	1	2	3	4	5
Predictor	TEMP	DEWPT	DSPREP	MUCK	LURGI
r^2	.522	.633	.664	.688	.713
Increase in r^2	.522	.111	.031	.024	.025
(α) associated with adding variable to regression	.0001	.0001	.006	.011	.008

Table 2-14. Results of Stepwise Regressions of Particulate Concentrations for Sites 1, 2 and 3 During the 1980 Summer Season, Tract C-a

Site 1 Data (48 cases)

Step	1	2	3
Predictor	DSPREP	TEMP	BDPS
r^2	.343	.412	.493
Increase in r^2	.343	.069	.081
(α) associated with adding variable to regression	.0001	.026	.011

Site 2 Data (34 cases)

Step	1	2
Predictor	PRECIP	MAXWS
r^2	.186	.281
Increase in r^2	.186	.095
(α) associated with adding variable to regression	.0109	.050

Site 3 Data (45 cases)

Step	1	2
Predictor	TEMP	DEWPT
r^2	.313	.505
Increase in r^2	.313	.192
(α) associated with adding variable to regression	.0001	.0002

Table 2-15. Results of Stepwise Regressions of Particulate Concentrations for Sites 1, 2 and 3 During the 1979-80 Winter Season, Tract C-a

Site 1 Data (50 cases)

Step	1	2
Predictor	DSPREP	WS
r^2	.224	.372
Increase in r^2	.224	.148
(α) associated with adding variable to regression	.0005	.0017

Site 2 Data (30 cases)

Step	1	2	3
Predictor	TEMP	DSPREP	LURGI
r^2	.242	.365	.455
Increase in r^2	.242	.123	.090
(α) associated with adding variable to regression	.0057	.0104	.0482

Site 3 Data (46 cases)

Step	1	2	3	4	5
Predictor	TEMP	DEWPT	LURGI	MUCK	DSPREP
r^2	.206	.322	.393	.482	.536
Increase in r^2	.206	.116	.071	.089	.054
(α) associated with adding variable to regression	.0015	.0096	.0075	.012	.037

at least 0.10 inch of precipitation was recorded) at Site 1 and dewpoint at Sites 2 and 3. Dewpoint was negatively correlated with TSP, indicating that low dewpoints (very dry air) were associated with high TSP concentrations. In the yearly data set, site activity variables rated no better than third most important at Site 1 (MUCK) and fourth and fifth most important at Site 3 (MUCK and LURGI). In no case did they individually contribute more than 0.03 to the r^2 value.

- It is interesting to note that at the treatment site (Site 3) the regression analysis on the annual data set for 1979-1980 ranked the same four predictors in the same order as did the regression analysis for the 1978-79 data set; namely, three meteorological parameters (TEMP, DEWPT, and DSPREP) followed by a site activity parameter (MUCK). Curiously, the r^2 values for the two years using these four predictors were identical (0.69). The only change between the years was the addition of LURGI as the fifth significant predictor in the current year's data set.

- During the winter season at Site 3, LURGI moved up to the third ranked predictor. It is to be expected that the Lurgi access road construction activity would be a more important predictor in the winter than yearly data set, since the road construction did not begin until November, 1980. Nonetheless, even though Site 3 is less than one mile down Corral Gulch from the Lurgi access road, Table 2-14 shows that it was not a major factor in explaining the variation in TSP concentrations during the winter (r^2 increase due to Lurgi is 0.07). Apparently, either the fugitive dust generated by the road construction activity settles out rapidly, having only a minor impact at that distance, or the meteorological effects mask the impacts of the road construction.

- The regression analysis at Site 2 using the winter data set indicated that the concentration of the Lurgi access road was the third most important predictor. However, it is not clear how this could occur, since Site 2 is four miles from the access road, and there is a large

gulch (Box Elder Gulch) between the two points. This result is suspect partially because the sample size is fairly small (30 cases), and the fact that the winter TSP concentrations are often near the detectable limit of the measurement method.

One very important consideration related to this last point, which should be kept in mind when evaluating these results, is the relative importance of the particulate concentrations during the summer and winter seasons. That is, the particulate concentrations at each site during the winter season (with a semi-permanent snow cover) are generally quite low and tend to have minimum variations. On the other hand, the summer season is characterized by large variations in the particulate concentrations with occasional periods of very high concentrations. Thus, the variation in the particulate concentrations during the winter is more difficult to predict and is also of less concern, because it is associated with very low particulate concentrations.

d. Conclusions - A number of statistical analyses were performed on the TSP data. A correlation analysis showed that Sites 1 and 2 (the control sites) were highly correlated, while the correlations between these sites and Site 3 (the treatment site) were slightly less. It was noted that the correlations between the control and treatment sites have increased, perhaps due to paving of the main tract access road and the movement of the Site 3 monitor away from a local dirt road.

The Site 3 monitor was moved 150 ft. from a lightly traveled but dusty access road in late June of the current year. Five months of simultaneous TSP data were collected at both locations to determine if the move had any impact on the TSP concentrations. No significant difference between the data sets was detected by a t-test.

A multiple regression analysis was run using a combination of eleven meteorological and site activity variables. The variables chosen explained approximately two-thirds of the variation in annual TSP concentrations at each of the sites, a result very similar to that found during the two previous years.

The stepwise multiple regression analysis showed that the meteorological parameters were more important than site activity parameters in explaining the variation in TSP concentrations. The daily mean temperature alone explains over half the annual variations. Temperature is the only variable used that has a distinctly annual cycle similar to TSP concentrations, but in fact there may be more important ones (such as soil moisture). However, it serves as an easily measured indicator variable.

Measures of site activity seemed to be most successful as predictors at Site 3, although they also met the test of significance at Sites 1 and 2. In no case did the site activity variable rank higher than third in importance in explaining the TSP variability.

The conclusion after three years of attempts to determine the most important factors affecting TSP concentrations at Tract C-a is that apparently no more than two-thirds of the source of the variability can be determined. There is apparently either a strong random component that accounts for the last one-third of the variability (such as noise in the measurement technique), or some of the parameters which are affecting TSP concentrations are not being included in the regression analysis. The situation may easily be the result of a combination of these two factors.

2.2 METEOROLOGY

Meteorological parameters are monitored to provide information on the general climate of Tract C-a and vicinity. They will also provide a basis for estimating the potential impact of emissions that may result from tract development and operation. Three meteorological sites have been in operation since the first quarter of the MDP. Meteorological data are taken at the 10-m level at each site, and also at the 60-m level at Site 1, the main sampling site. The parameters measured at each site are given in Table 2-1. Site 1 is at an elevation of 7,335 feet above mean sea level (MSL) just west of the tract boundary. Site 2 is at an elevation of 7,360 feet MSL to the southwest of the tract. Site 3 is located just east of the tract boundary in a broad gulch, at an elevation of 6,580 feet MSL. A topographic map showing the locations of the three sites for the MDP program has been presented (Environmental Monitoring Sites Map 1--Physical, in map pocket). This section of the report deals primarily with the meteorological data collected from the three sites during the MDP period December 1979-November 1980 (hereafter referred to as the current year). Meteorological data for Site 1 are presented in Appendix 2-2.1, and data for Sites 2 and 3 are presented in Appendix 2-2.2. Precipitation data and snow depth measurements are presented in Appendices 2-2.3 and 2-2.4, respectively. Barometric pressure data are presented in Appendix 2-2.5. The data for the baseline period and the first year of the MDP period were extracted from earlier reports (RBOSP 1977, RBOSC MDP Monitoring Report 3, and RBOSC MDP Monitoring Report 5) for comparison purposes.

A. Temperature and Stability

1. Objectives

Ambient air temperature, a primary climatic parameter, provides basic information on monthly and year-to-year variability of climatic conditions at the C-a tract. The measured vertical temperature differential within the lowest boundary layers can be utilized to determine the stability of the atmosphere. Atmospheric stability strongly influences the dispersion of emissions into the atmosphere and is therefore an important input into air quality models.

2. Methods

The methods followed for collection of temperature data were described in RBOSC MDP Monitoring Report 3 and are not repeated herein.

3. Results and Discussions

Table 2-16 presents a summary of monthly, seasonal and annual temperature statistics for the current year at each of the three monitoring sites on the tract (10-m level). The temperature statistics presented for each site include means, average daily maxima, average daily minima, absolute maxima, and absolute minima.

The monthly mean temperatures for the three sites are very similar, except that Site 3 was somewhat lower than the other sites most of the time. The mean annual temperatures were 7.5 C at Site 1 and 6.3 C at Site 3. The annual temperature at Site 2 was not calculated because only 10-month data were available due to data acquisition problems in the latter part of the year.

Absolute maximum temperatures and absolute minimum temperatures at Site 1 and Site 2 were very similar, but they were more extreme at Site 3. The extreme temperatures recorded at the tract during the current year (both at Site 3) were 31.0 and -22.9 C. Similarly, the average daily maximum and minimum temperatures at Site 3 were more extreme than those at Site 1 and Site 2.

The greater temperature range at Site 3 may be explained by examining the differences in site topography. Evening and late night conditions in the area are typically characterized by clear skies and light winds, resulting in strong radiational cooling at the higher elevations and subsequent drainage of the cold, dense air to lower elevations by way of the extensive gulch network. Site 3, situated in a valley, receives this cold air drainage flow from the higher elevations to the West. Sites 1 and 2 are on locally high terrain so that the cold air drains away. Due to this local circulation, Site 3 exhibits the coldest nighttime temperatures of the three sites. During the day, however, Site 3 reaches warmer maximum temperatures than Site 1 or Site 2 because of its lower elevation and the strong surface heating in the gulch.

Table 2-16. Monthly, Seasonal, and Annual Summary of Temperatures (°C) (Mean, Average Daily Maximum, Average Daily Minimum, Absolute Maximum, Absolute Minimum) December 1979 - November 1980, 10-m Level of Site 1, Site 2 and Site 3, RBOSC Tract C-a

	Site 1					Site 2					Site 3				
Period	Mean	Avg Daily Max	Avg Daily Min	Abs Max	Abs Min	Mean	Avg Daily Max	Avg Daily Min	Abs Max	Abs Min	Mean	Avg Daily Max	Avg Daily Min	Abs Max	Abs Min
Monthly															
December	0.1	2.5	- 2.9	8.3	-10.5	0.6	5.1	- 2.9	8.6	-10.7	- 3.1	3.7	- 9.5	10.9	-19.8
January	- 4.7	- 1.1	- 7.7	4.7	-15.3	- 4.1	0.2	- 7.2	4.2	-15.8	- 4.7	1.4	-10.3	7.1	-17.8
February	- 1.1	2.0	- 4.0	9.2	-15.5	1.5	4.6	- 1.9	9.5	- 9.3	- 1.5	4.5	- 6.5	12.4	-22.9
March	- 1.8	1.5	- 5.2	6.8	-11.9	- 1.3	2.3	- 5.1	6.9	-12.5	- 0.9	4.5	- 6.7	10.0	-19.0
April	4.7	8.7	0.5	18.8	- 9.1	7.6	11.9	2.5	18.9	- 7.0	5.1	12.1	- 2.6	21.8	-10.9
May	8.4	12.3	4.4	21.2	- 1.2	8.9	13.0	5.0	21.6	- 1.0	9.5	15.4	2.9	24.2	- 3.8
June	17.8	21.9	12.9	27.5	5.4	18.4	22.2	13.0	27.0	5.2	15.9	24.0	5.9	29.2	1.3
July	20.6	24.8	16.3	28.0	11.1	20.9	24.8	17.2	29.0	12.4	20.1	26.6	11.2	31.0	5.4
August	18.6	23.1	13.8	28.0	5.9	20.6	23.9	15.5	30.0	8.6	16.1	24.0	8.0	29.0	1.3
September	15.8	19.8	11.7	24.8	1.9	16.0	20.1	11.5	25.4	3.9	13.5	21.6	4.6	27.2	- 1.4
October	7.8	11.8	3.8	21.7	- 5.7	NA	NA	NA	NA	NA	4.0	12.8	- 3.0	24.0	-10.5
November	3.3	6.7	0.2	16.3	-10.6	NA	NA	NA	NA	NA	0.8	8.4	- 5.8	18.2	-14.9
Seasonal															
Winter (Dec, Jan, Feb)	- 1.9	1.1	- 4.9	9.2	-15.5	- 0.5	3.3	- 4.0	9.5	-15.8	- 3.1	3.2	- 8.8	12.4	-22.9
Spring (Mar, Apr, May)	3.8	7.5	- 0.1	21.2	-11.9	5.1	9.1	0.8	21.6	-12.5	4.6	10.7	- 2.1	24.2	-19.0
Summer (Jun, July, Aug)	19.0	23.3	14.3	28.0	5.4	20.0	23.6	15.2	30.0	5.2	17.4	24.9	8.4	31.0	1.3
Fall (Sept, Oct, Nov)	9.0	12.8	5.2	24.8	-10.6	NA	NA	NA	NA	NA	6.1	14.3	- 1.4	27.2	-14.9
Annual	7.5	11.2	3.6	28.0	-15.5	NA	NA	NA	NA	NA	6.3	13.3	- 1.0	31.0	-22.9

The temperature record allows the calculation of the length of the frost-free period at each site. This information is helpful in determining the required hardiness and suitability of plants that will be used in revegetation of the tract. However, it should be noted that these temperatures are measured at 10 m above ground level, so that the first and last excursion below 0 C at 10 m (as used here) probably represents a "hard frost" at the ground surface.

Table 2-17 presents the frost-free period for the last three years at the three sites. The table also provides the 1980 frost-free period for several climatological stations located in the vicinity of the tract. It should be noted that the National Weather Service stations measure the temperature at 2 meters, so the data are not strictly comparable to the data taken at the tract. However, they are included for reference.

The table shows that the frost-free period at Sites 1 and 2 has ranged from 111 to 144 days over the last three years, with the longest period being the current one. Site 3, being exposed to cold air drainage flows at night, has had a consistently shorter frost-free period than the other sites. Over the last three years, it has ranged from 75 to 120 days, with the current year also being the longest.

The frost-free periods at Meeker and Rangely are generally comparable to that measured on the tract, but at Grand Junction the period is significantly longer. This is due at least partially to the lower elevation (4800 ft. at Grand Junctio vs. 7,000 ft. at the tract), and the somewhat protected valley in which Grand Junction is situated.

Table 2-18 provides a summary of annual absolute minimum, absolute maximum, and mean values of the air temperature recorded at the three sites during each of the five years of data collected to date, as well as the five data years combine The five-year temperature record shows that the first year of the Modular Development Phase (1977-78) had slightly higher temperatures compared to the other years of record.

Stability classification (A-G), based upon temperature differences (ΔT) within a short vertical distance of the surface, are based on those in the Nuclear

Table 2-17. Frost-free Period for Sites 1, 2, and 3 During the Last Three Years, and the 1980 Frost-free Period for Climatological Stations Surrounding Tract C-a

	Frost-Free Period											
	Site 1		Site 2		Site 3		Meeker		Rangely		Grand Junction	
Year	Length (Days)	Dates	Length (Days)	Dates	Length (days)	Dates	Length (Days)	Dates	Length (Days)	Dates	Length (Days)	Dates
1980	144	05/25-10/16	NA	NA	120	05/26-09/23	101	06/02-09/11	123	06/02-10/03	192	04/14-10/23
1979	133	06/09-10/20	133	06/09-10/20	105	06/01-09/14						
1978	111	05/31-09/19	111	05/31-09/19	75	06/01-08/15						

Table 2-18. Summary of Annual and Combined Five-Year Onsite Climatology of Absolute Minimum, Absolute Maximum and Mean Values of Temperature (C) During the Baseline and MDP Periods, Tract C-a

Temperatures[1/]	2/75-1/76	2/76-1/77	12/77-11/78	12/78-11/79	12/79-11/80	Entire 5-Year Period
Site 1 (10m level)						
Absolute Minimum	-21.1	-21.7	-14.5	-24.6	-15.5	-24.6
Absolute Maximum	30.1	29.7	30.4	28.5	28.0	30.4
Mean	6.1	7.2	7.6	6.0	7.5	6.9
Site 2 (10m level)						
Absolute Minimum	-21.4	-22.2	-16.1	-26.3	-15.8	-21.4
Absolute Maximum	27.5	29.4	30.5	28.9	30.0	30.5
Mean	5.5	6.9	7.9	6.4	NA	6.7
Site 3 (10m level)						
Absolute Minimum	-28.2	-25.3	-23.1	-29.6	-22.8	-29.6
Absolute Maximum	29.0	32.1	32.4	31.2	31.0	32.4
Mean	4.3	5.7	6.7	5.0	6.3	5.6

[1/] Minimum and maximum annual temperatures are based on hourly values for each 1-year period

Regulatory Commission (NRC) Regulatory Guide 1.23 (NRC 1972). The most turbulent and unstable conditions are characterized by A stability, and the least turbulent and most stable conditions are characterized by G stability.

Table 2-19 presents the frequency distribution of stability classes by month and season for Site 1, based on data from the current year. Unstable (classes A, B and C) conditions occurred predominantly during the summer. The occurrence of stable conditions showed less seasonal dependence.

B. Dewpoint

1. Objectives

Dewpoint data, collected since late July 1978, is used to evaluate potential cooling system alternatives. The data are more directly useable than relative humidity data, which were collected onsite for the same purposes during the baseline period and from December 1977 to late July 1978. Relative humidity can be determined from concurrent dewpoint and temperature measurements.

2. Methods

The methods followed for collection of dewpoint temperature data were described in RBOSC MDP Monitoring Report 4 and are not repeated herein.

3. Results and Discussion

The average dewpoint for the current year was -6.1 C. The range of dewpoints was -25.0 to 11.6 C.

C. Wind Speed and Wind Direction

1. Objectives

The wind speed and wind direction influence atmospheric dispersion. Measurement of the frequency of occurrence of wind speed and wind direction classes can be used in interpreting air quality data.

Table 2-19. Monthly, Seasonal, and Annual Occurrence of ΔT Stability Classes, December 1979 - November 1980, Site 1, Tract C-a

	STABILITY INDEX							
PERIOD	A	B	C	D	E	F	G	TOTAL
Jan	0	0	0	183	318	68	3	572
Feb	0	0	0	229	424	62	10	725
Mar	0	1	0	357	346	22	0	726
Apr	18	13	29	286	308	56	5	715
May	42	29	33	265	272	42	0	683
Jun	66	37	46	143	190	116	13	611
Jul	48	45	42	150	211	90	9	595
Aug	100	44	39	122	261	70	2	638
Sep	54	35	35	103	209	80	4	520
Oct	12	10	22	135	193	43	1	416
Nov	6	11	21	200	353	46	0	637
Dec	0	0	0	38	135	42	9	224
Spring	60	43	62	908	926	120	5	2124
Summer	214	126	127	415	662	276	24	1844
Fall	72	56	78	438	755	169	5	1573
Winter	0	0	0	450	877	172	22	1521
Annual	346	225	267	2211	3220	737	56	7062

2. Methods

The methods followed for collection of wind data were described in RBOSC MDP Monitoring Report 3 and are not repeated herein.

3. Results and Discussion

Seasonal and annual wind roses for each of the three sites for the current year are presented in Figures 2-15 to 2-22.

The Site 1 annual 10-m level wind rose for 1979-80 shows the prevalent wind direction to be from the west-southwest (WSW on wind rose), with secondary maxima from the south-southwest (SSW on wind rose) and southwest (SW on wind rose). The mean wind speeds associated with these directions were 8.0 mph, 9.0 mph, and 6.7 mph, respectively. These data compare well with the two annual wind roses during the baseline and the two annual wind roses during the MDP phase for the 10-m level at Site 1, which all show the prevalent wind direction to be from the west-southwest. At Site 1, the wind direction, with the lowest frequency of occurrence as well as the lowest annual average wind speeds, was the southeast quadrant during all five years. The north and the north-northeast were directions of secondary wind speed maxima at Site 1 during the five-year period.

The Site 2 annual 10-m level wind rose for the current year shows the prevalent wind direction to be from the south-southwest, with secondary maxima from the west, west-southwest and from the south-southwest. The mean wind speeds associated with these directions were 13.1 mph, 8.7 mph, 8.3 mph, and 13.0 mph, respectively. These data closely resemble the earlier data, which also show the prevalent wind directions to be from the west and southwest. The wind directions having the lowest frequency of occurrence and the lowest annual average wind speeds are in the southeast quadrant at Site 2, similar to those found at Site 1.

The Site 3 annual 10-m level wind rose for the current year shows the prevalent wind direction, by far, to be from the west (39.8 percent of total annual occurrences), with secondary maxima from the west-southwest and the southwest. The mean wind speeds associated with these directions were 6.5 mph, 8.2 mph,

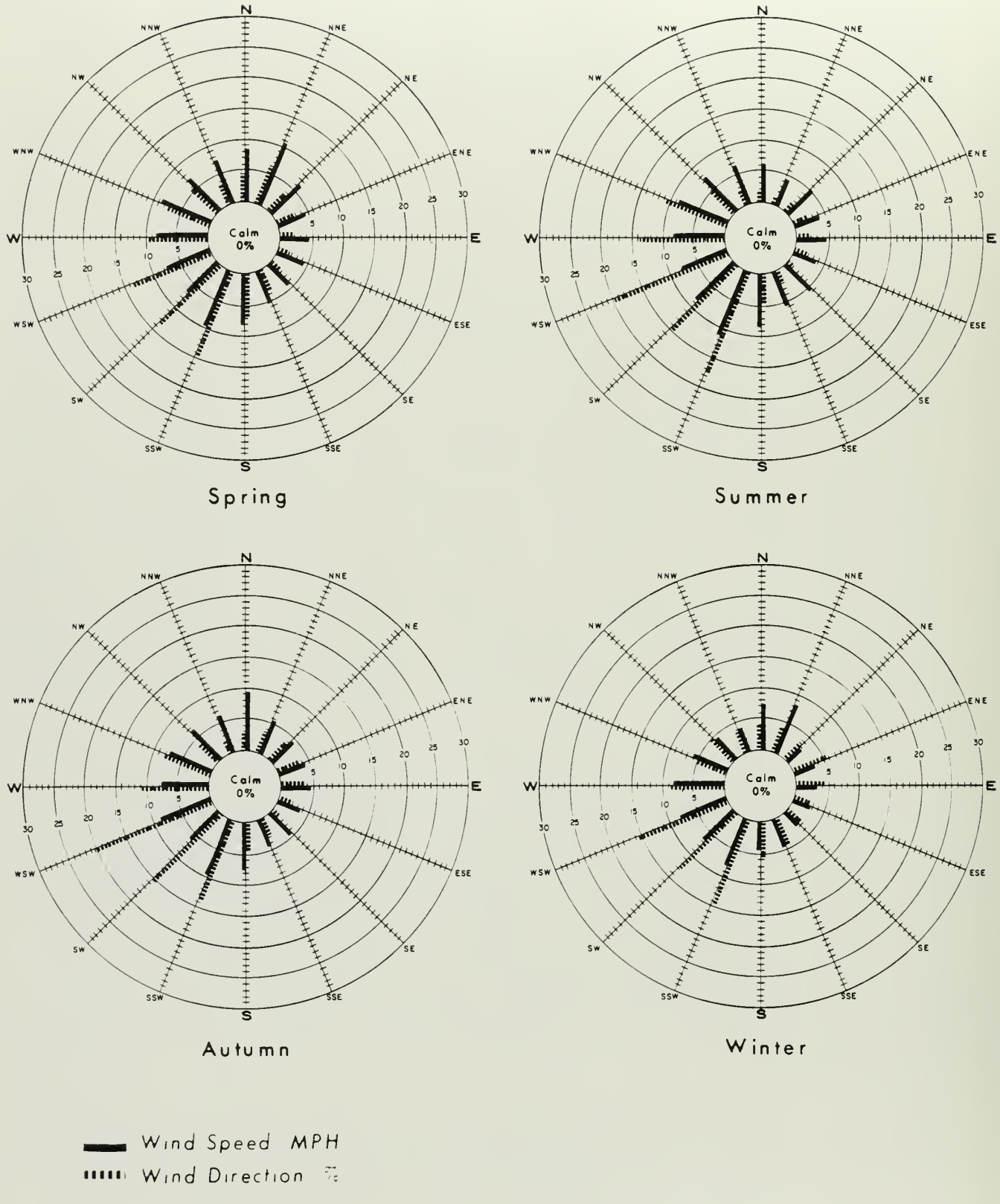

Figure 2-15. Seasonal Wind Roses, Dec 1979-Nov 1980, 10-m Level at Site 1, Tract C-a

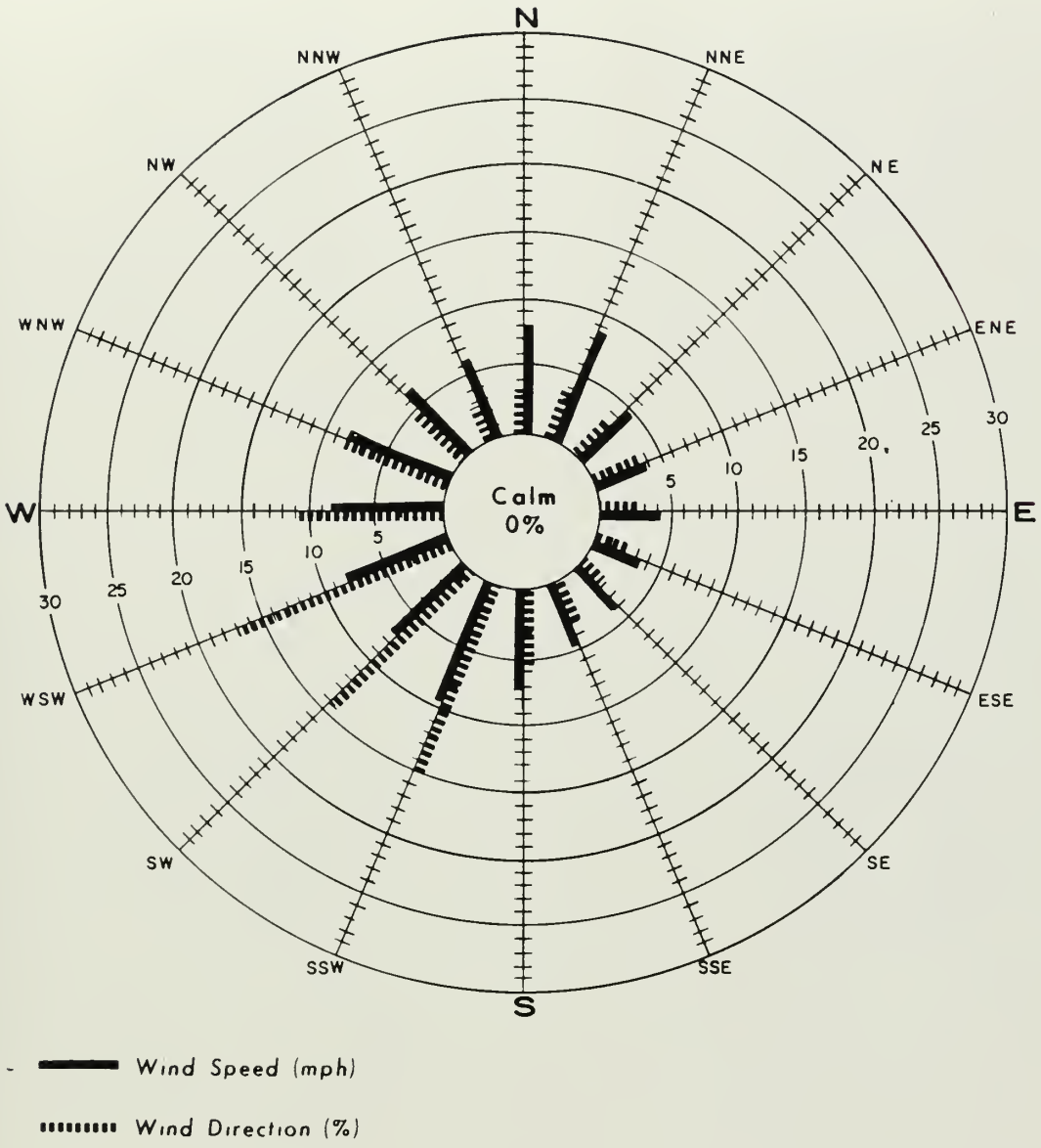

Figure 2-16. Annual Wind Rose, Dec 1979-Nov 1980, Site 1.10 m Level, Tract C-a

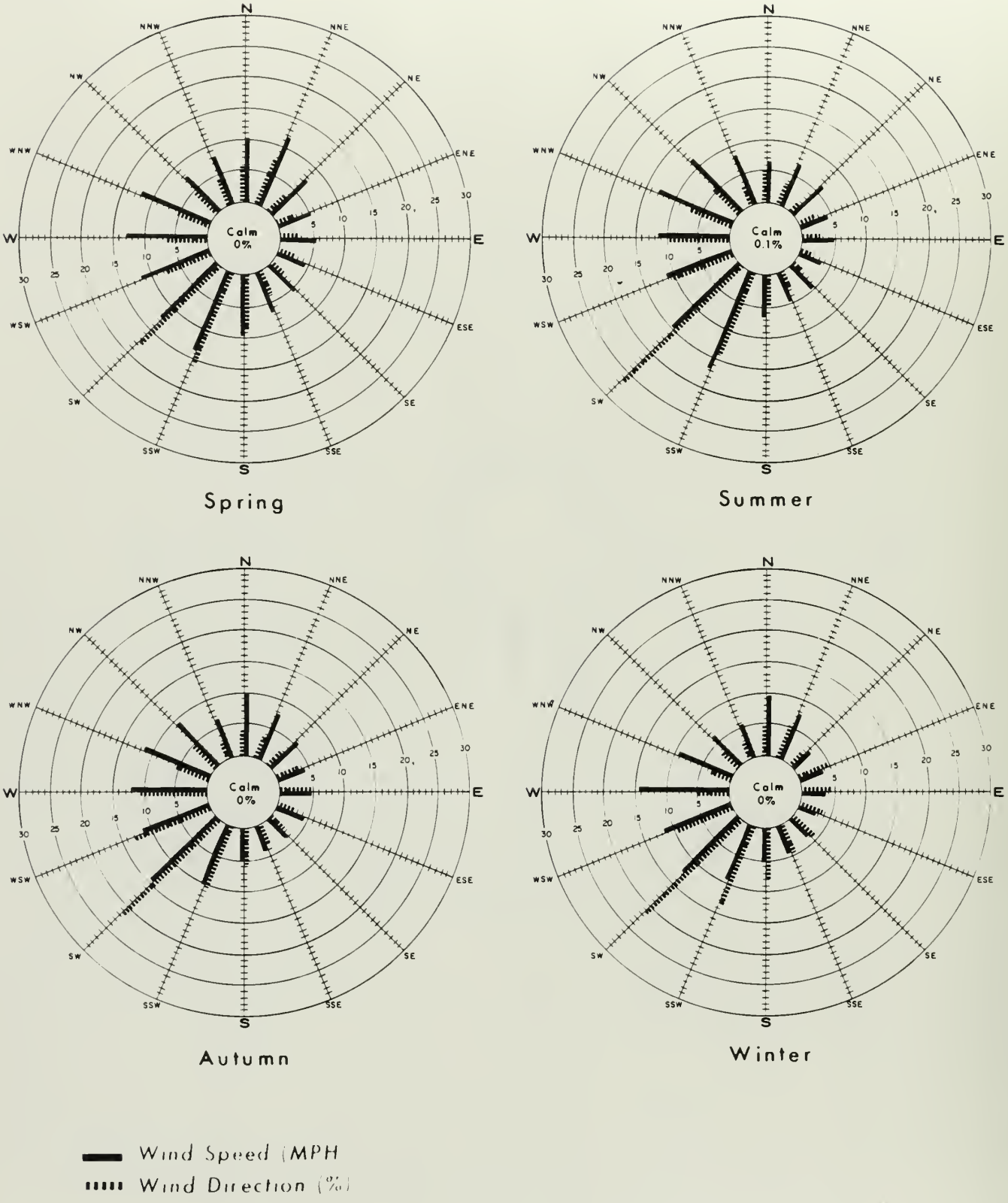

Figure 2-17. Seasonal Wind Roses, Dec 1979-Nov 1980, Site 1 60 m Level, Tract C-a

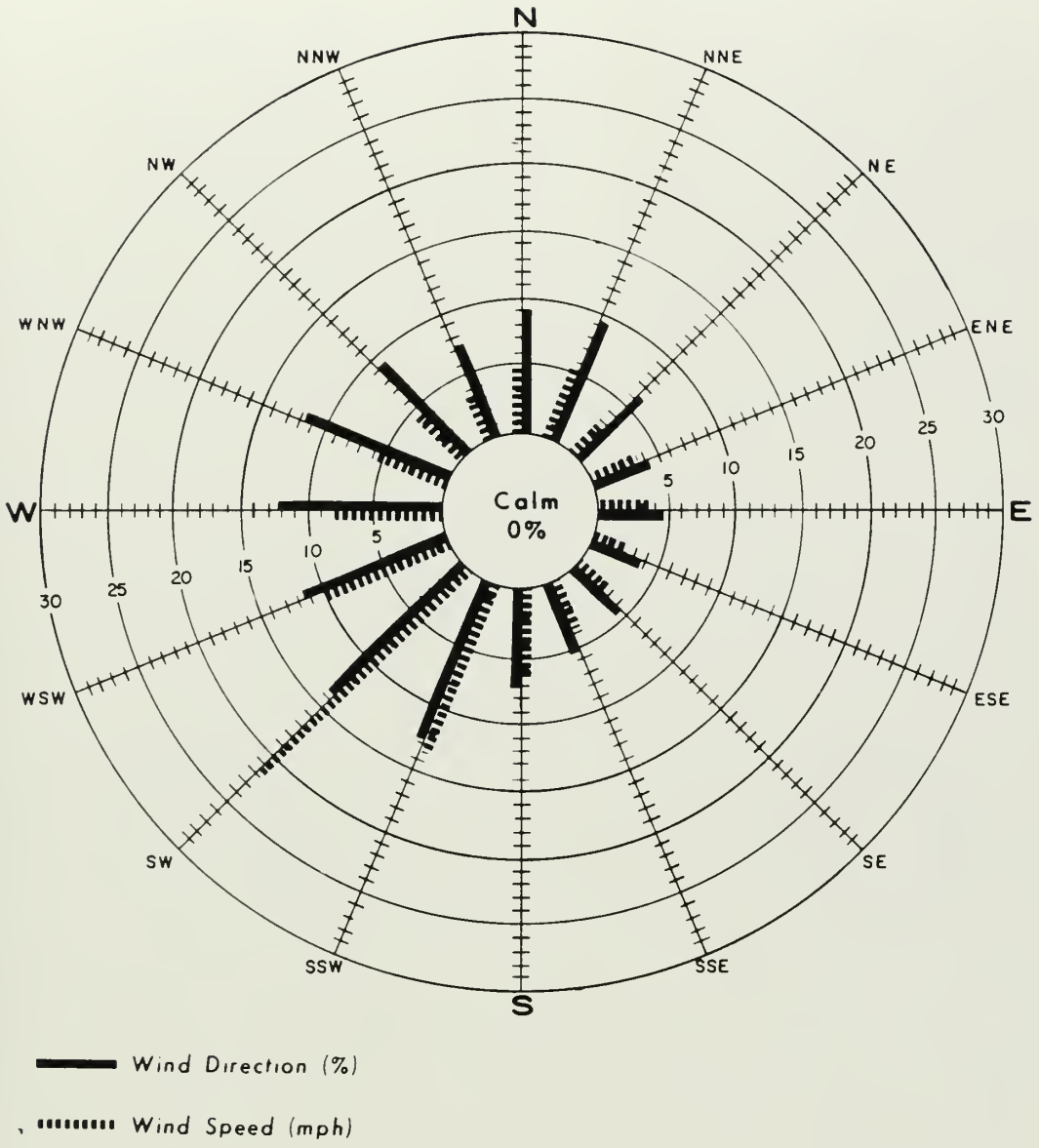

Figure 2-18. Annual Wind Rose, Dec 1979-Nov 1980, Site 1 60 m Level, Tract C-a

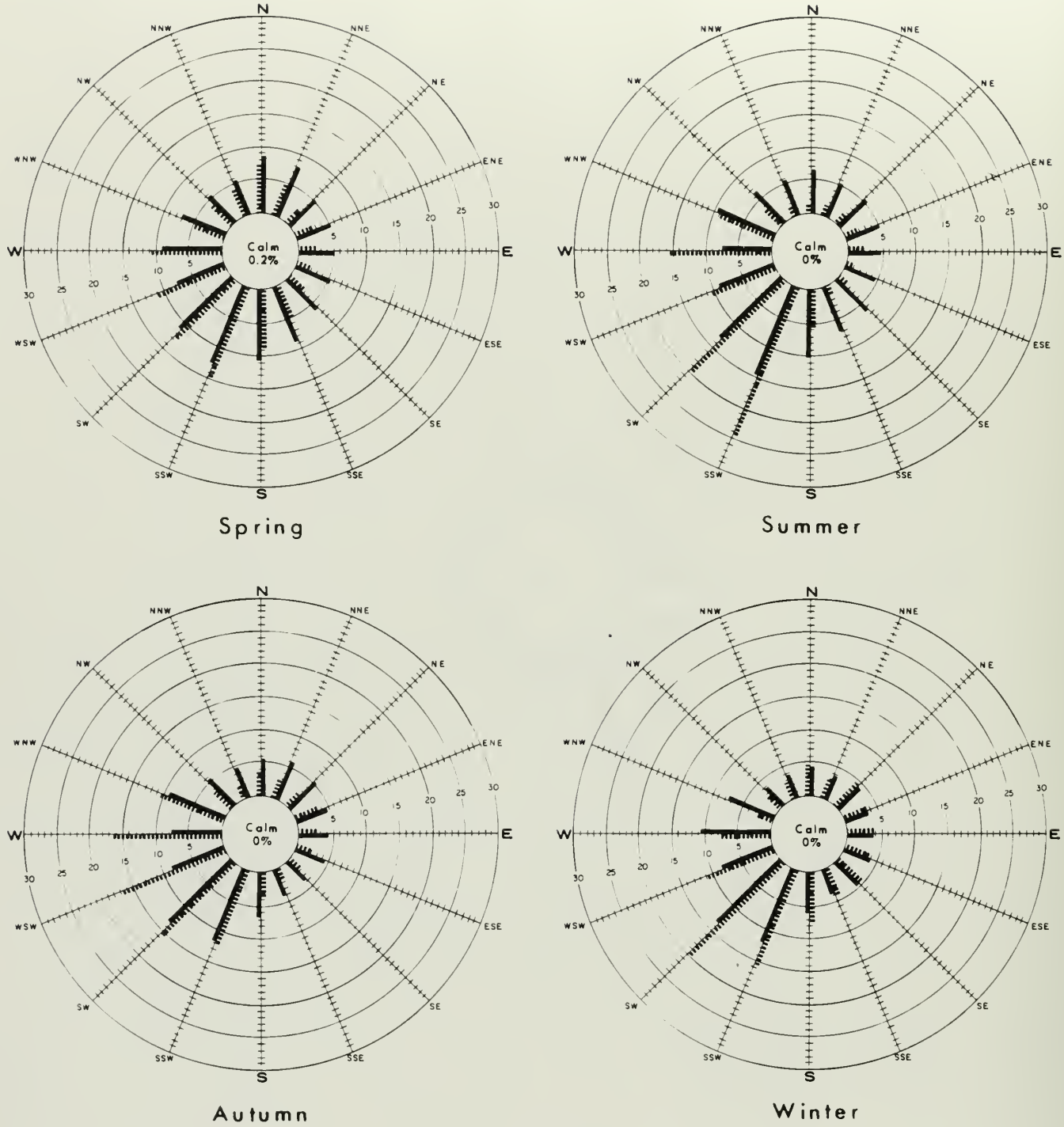

Figure 2-19. Seasonal Wind Roses, Dec 1979-Nov 1980, Site 2 10 m Level, Tract C-a

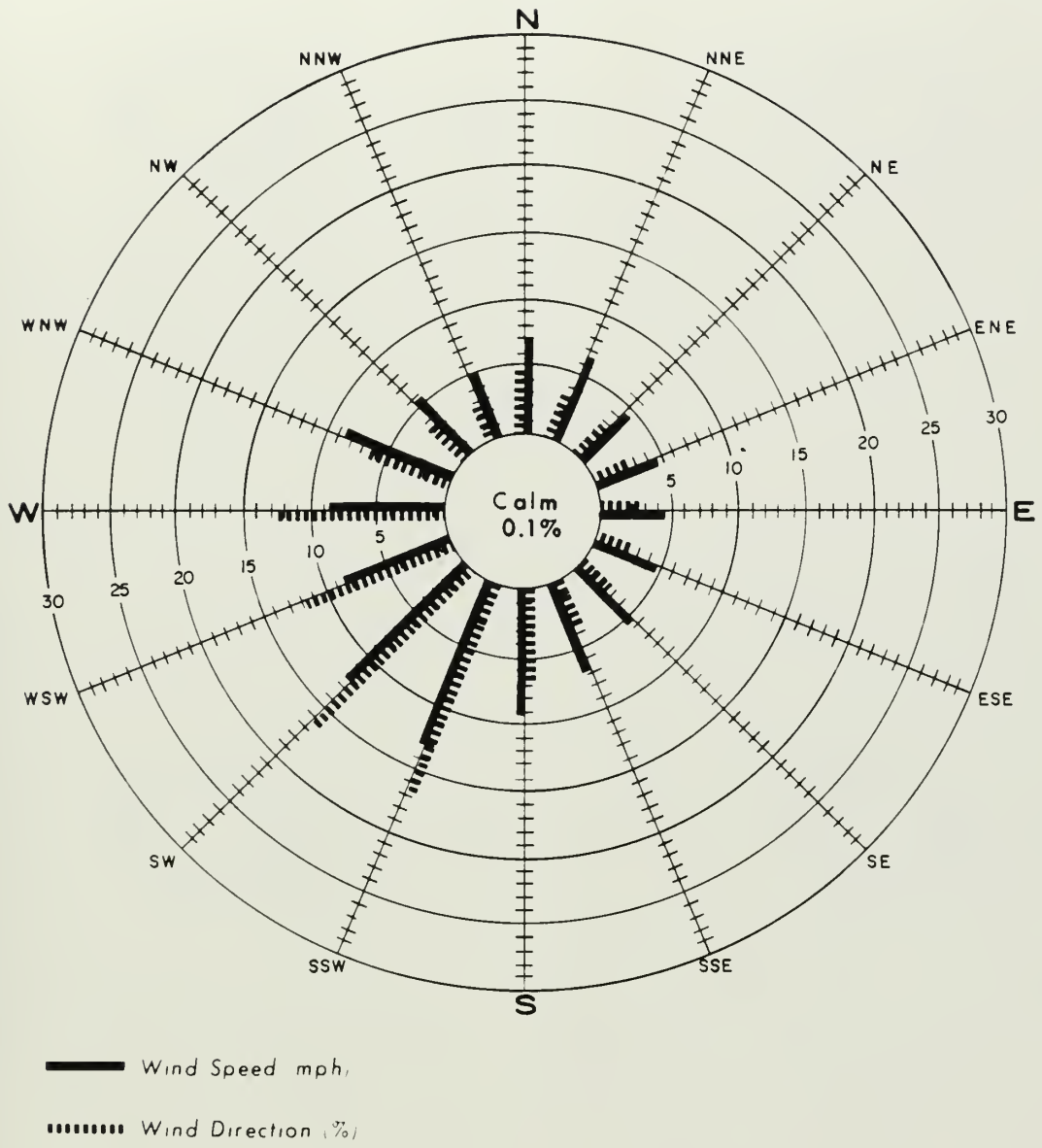

Figure 2-20. Annual Wind Rose, Dec 1979-Nov 1980, Site 2 10 m Level, Tract C-a

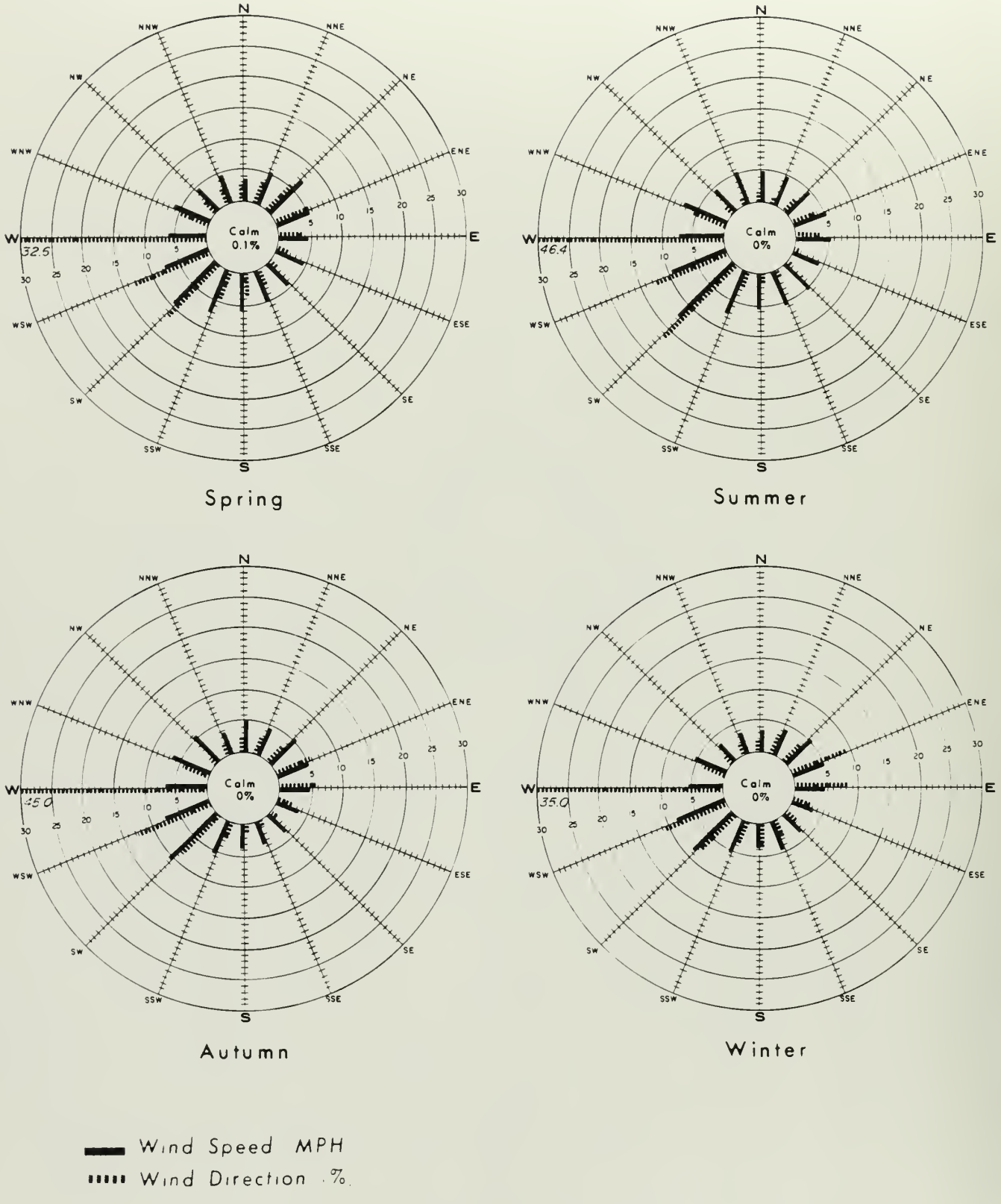

Figure 2-21. Seasonal Wind Roses, Dec 1979-Nov 1980, Site 3 10 m Level, Tract C-a

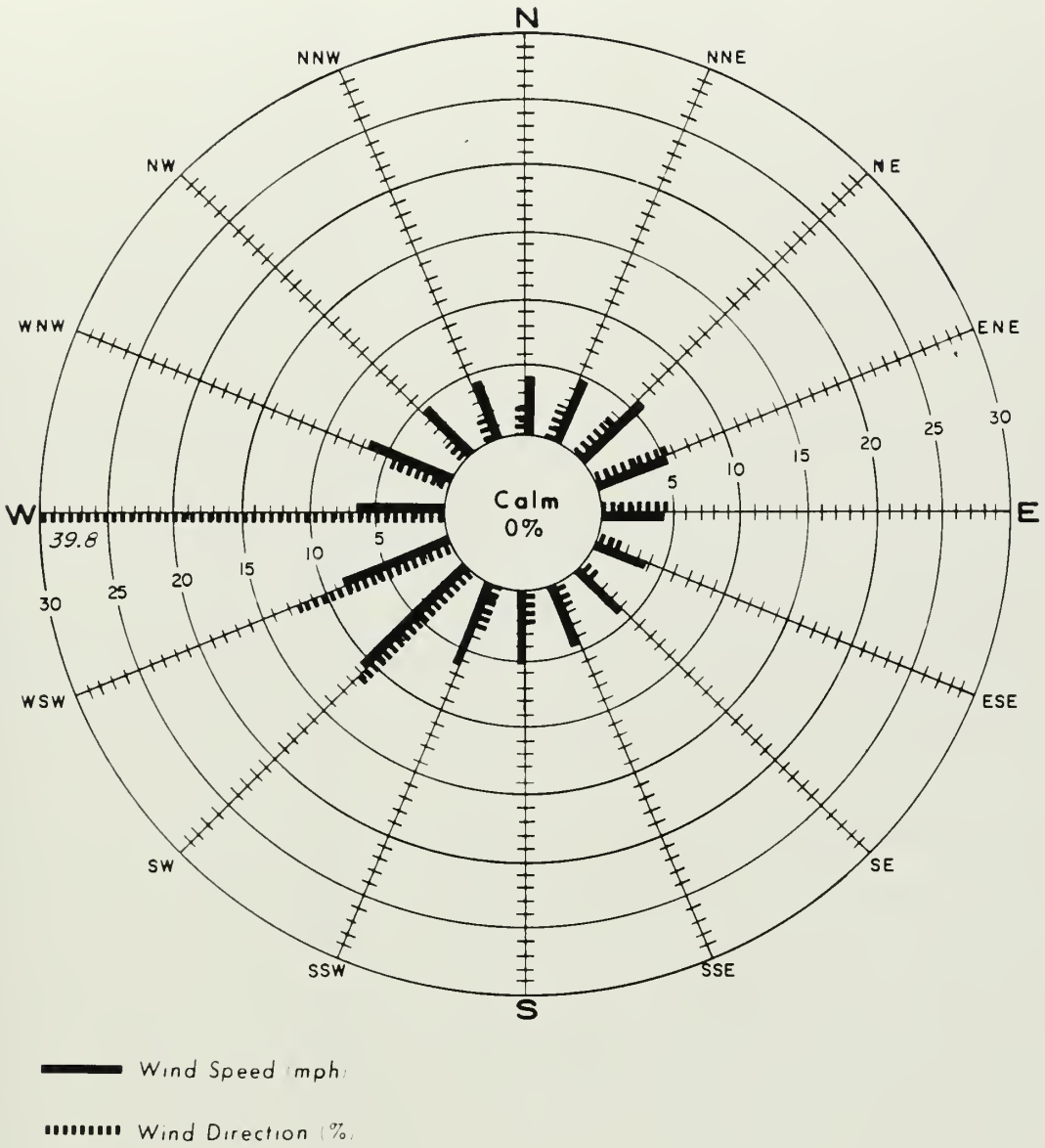

Figure 2-22. Annual Wind Rose, Dec 1979-Nov 1980, Site 3 10 m Level, Tract C-a

and 10.8 mph, respectively. These data are similar to the previous years of record, which also show a predominance of westerly winds. This is the result of the general westerly circulation combined with nighttime drainage winds down Corral Gulch.

Table 2-20 contains a summary of the absolute maximum and mean hourly wind speeds recorded at each of the three sites during each of the data years. The mean wind speeds for the three sites during the current year are 7.3 mph at the Site 1 10-m level, 10.0 mph at the Site 1 60-m level, 8.8 mph at Site 2 and 6.6 mph at Site 3. As shown in Table 2-20, there has been little variation in the mean wind speed during the period of record. The decrease in mean wind speeds from Site 2 (highest) to Site 3 (lowest) reflects the relative degree of sheltering by the local terrain.

Tables 2-21 to 2-24 present the annual frequency of wind direction occurrences by hour for each of the three sites (including the 60-m level at Site 1) during the current year. These tables show the same data as given in the annual wind roses, but also illustrate the variation throughout the day. Each site shows the dominance of westerly winds. The Site 3 winds show the most extreme case, where winds from the 22.5° west sector occurred more than 70 percent of the time in the early morning hours. These winds are associated with downvalley drainage flows, as discussed earlier.

The most noteworthy event evident illustrated in Tables 2-21 to 2-24 is the diurnal variation in the wind direction. It is to be expected that the downvalley wind at Site 3 would reverse and become an upvalley wind shortly after sunrise, due to local solar heating of the terrain. The effect becomes moderately strong and results in an upvalley flow (against the general westerly circulation) approximately 35-40 percent of the time during the morning hours of 0900 and 1000. Also interesting is the fact that this morning upvalley flow occurs at all three of the sites. At the 10-m level at Sites 1 and 2 it occurs approximately 25 and 20 percent of the time, respectively. These upslope easterly winds are much less common at other times of the day. In addition, this upslope flow appears to be fairly deep, since these easterly winds also occur approximately 20 percent of the time at 0900 hours at the 60-m level at Site 1.

Table 2-20. Summary of Annual Absolute Maximum and Mean Values of Wind Speed (MPH) at Tract C-a During Baseline Period (February 1975-January 1976, February 1976-January 1977) and the MDP Period (December 1977-November 1978, December 1978-November 1979, & December 1979-November 1980)

	Maximum[1/]					Mean					Five-Year Combined Mean
	1975-1976	1976-1977	1977-1978	1978-1979	1979-1980	1975-1976	1976-1977	1977-1978	1978-1979	1979-1980	
Site 1											
10m Wind Speed	30.8	32.3	30.0	27.5	31.6	7.7	7.2	7.6	7.3	7.3	7.4
60m Wind Speed	43.0	56.6	41.5	36.8	40.8	10.6	10.0	10.6	9.6	10.0	10.2
Site 2											
10m Wind Speed	36.7	39.2	39.0	36.1	37.8	9.1	8.4	9.2	8.4	8.8	8.8
Site 3											
10m Wind Speed	29.9	26.4	26.0	24.5	26.1	6.6	6.9	6.7	6.2	6.6	6.6

[1/] Hourly values for this period

Table 2-21. Wind Direction Frequency (%) by Hour of Day, December 1979 - November 1980, 10 m Level at Site 1, Tract C-a

Hr. of Day	WIND DIRECTION																
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Calm
1	3.2	2.5	1.1	1.4	0.7	0.4	1.1	2.8	3.5	12.1	16.3	24.8	12.4	9.6	5.0	3.2	0.0
2	4.3	3.2	1.4	1.4	0.7	0.4	1.1	0.7	5.3	12.8	14.2	21.7	16.0	7.1	4.6	5.0	0.0
3	3.6	2.9	1.8	1.4	0.4	0.7	0.0	2.1	7.1	9.6	15.0	23.6	16.4	8.6	3.6	3.2	0.0
4	2.2	2.5	1.8	0.7	0.4	1.4	1.1	4.7	3.6	10.1	17.3	22.4	11.6	11.2	5.1	4.0	0.0
5	1.4	2.5	1.4	1.8	1.4	2.2	2.5	4.3	4.7	13.4	14.5	22.1	10.9	7.6	5.1	4.0	0.0
6	2.9	4.4	1.8	1.1	1.1	2.2	1.1	7.0	7.0	12.8	17.2	15.8	10.3	7.7	5.1	2.6	0.0
7	4.4	5.1	5.1	5.1	3.6	4.0	2.2	6.6	8.8	15.7	6.9	16.1	6.6	3.6	2.9	3.3	0.0
8	2.9	4.7	4.7	10.4	5.8	6.5	2.2	7.6	10.1	15.1	7.6	11.2	5.4	2.5	1.8	1.8	0.0
9	2.1	3.1	9.1	8.0	7.0	3.8	6.3	5.6	8.7	13.6	8.4	12.2	5.6	1.7	1.7	3.1	0.0
10	2.4	3.4	9.2	8.2	6.5	4.1	1.4	3.1	8.2	13.7	12.3	13.0	9.9	2.1	2.1	0.3	0.0
11	3.0	6.4	4.1	5.7	6.4	2.0	1.7	1.7	5.4	17.6	11.5	14.5	10.5	4.4	2.0	3.0	0.0
12	3.1	4.4	4.1	6.1	5.4	1.0	0.3	2.0	8.2	19.7	12.2	12.6	10.5	4.8	4.4	1.0	0.0
13	2.7	5.8	4.1	6.5	2.7	1.0	0.3	1.7	5.1	22.2	9.9	13.7	11.3	6.5	4.1	2.4	0.0
14	2.4	4.1	3.0	3.0	3.7	2.0	0.3	1.0	3.7	22.0	11.8	9.8	15.2	7.8	7.1	3.0	0.0
15	3.4	4.8	3.1	3.1	3.4	2.0	1.0	1.0	3.7	18.7	15.6	8.8	10.9	10.5	5.4	4.4	0.0
16	3.0	6.4	3.0	2.0	4.7	1.0	1.3	2.0	6.7	19.1	12.4	9.7	7.4	10.7	7.4	3.0	0.0
17	3.8	5.5	2.1	1.7	1.7	2.1	1.0	2.7	3.4	21.9	15.1	9.2	6.5	10.3	9.2	3.8	0.0
18	3.1	4.8	1.0	1.4	0.3	0.3	1.4	2.0	5.1	19.5	16.7	13.0	9.2	11.9	6.5	3.8	0.0
19	3.8	2.4	1.0	0.7	0.0	1.4	1.0	2.4	3.1	15.7	17.7	19.8	9.2	14.7	5.8	1.4	0.0
20	3.5	3.1	1.4	1.7	0.3	0.7	0.7	2.1	2.8	10.4	14.2	26.6	14.5	10.7	6.2	1.0	0.0
21	3.1	2.4	2.1	1.7	0.3	1.0	0.7	1.4	3.1	10.1	18.5	25.5	11.9	10.8	6.3	0.7	0.0
22	5.3	1.8	2.1	1.4	0.4	0.7	2.1	4.2	3.5	10.6	15.5	23.9	12.0	8.1	4.6	3.9	0.0
23	3.5	2.1	1.1	1.4	1.4	1.1	1.8	2.5	3.2	10.2	18.0	23.6	14.1	9.6	3.5	3.5	0.0
24	4.9	2.8	1.8	0.4	0.7	1.1	1.8	1.8	3.5	11.0	19.4	20.8	13.8	8.5	4.6	3.2	0.0
All	3.2	3.8	3.0	3.2	2.5	1.8	1.4	3.0	5.3	15.0	14.1	17.2	10.9	8.0	4.8	2.9	0.0

Table 2-22. Wind Direction Frequency (%) by Hour of Day, December 1979 - November 1980, 60 m Level at Site 1, Tract C-a

Hr. of Day	WIND DIRECTION																
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Calm
1	7.7	6.3	2.5	0.7	1.8	2.5	2.1	3.9	7.4	11.2	21.1	13.7	7.0	5.3	3.5	3.2	0.4
2	6.7	5.6	2.5	2.1	2.8	1.1	2.1	3.2	8.1	10.2	21.8	11.6	8.1	6.3	4.6	3.2	0.4
3	5.7	4.9	1.4	2.5	1.8	2.8	2.8	4.6	6.7	11.3	21.2	11.3	8.8	4.6	4.9	4.6	0.0
4	7.1	4.3	3.2	2.5	0.7	2.5	3.2	3.2	8.9	11.1	24.3	8.6	8.2	3.9	2.9	5.4	0.0
5	4.3	3.6	2.2	3.2	1.4	1.4	3.2	5.7	10.4	11.8	24.0	7.9	9.0	3.9	2.9	5.0	0.0
6	6.9	5.8	2.9	1.8	3.2	0.7	1.8	2.5	10.8	17.0	20.9	9.7	4.7	3.6	2.9	4.3	0.4
7	4.0	5.8	3.3	3.6	4.0	3.6	4.4	5.5	11.3	14.5	17.8	9.1	5.1	2.9	2.2	2.9	0.0
8	3.2	3.9	4.6	7.1	7.5	5.0	6.4	5.0	11.1	12.1	15.7	9.3	5.7	0.4	2.1	0.7	0.0
9	1.0	4.1	3.8	8.3	7.9	3.1	4.8	5.9	7.6	14.5	16.9	10.0	6.2	1.4	2.1	2.4	0.0
10	2.0	5.1	3.1	9.5	6.8	3.1	4.7	4.1	4.4	16.3	15.6	11.9	8.8	2.0	2.0	0.7	0.0
11	3.1	5.4	2.0	3.7	6.5	3.7	3.1	2.0	4.4	16.7	19.7	11.2	10.5	5.1	1.4	1.4	0.0
12	3.7	3.7	1.4	4.4	6.8	1.7	2.0	1.0	5.7	15.2	22.0	10.8	11.1	4.4	3.7	2.4	0.0
13	4.1	5.4	2.7	2.7	5.1	2.0	0.7	1.4	3.4	18.6	17.6	10.8	11.9	7.8	4.1	1.7	0.0
14	3.0	3.3	1.3	4.3	3.3	2.7	1.0	1.7	2.0	14.0	21.4	10.4	12.7	9.7	6.4	2.7	0.0
15	3.0	4.4	1.0	5.4	2.0	2.7	2.0	1.4	2.0	15.2	21.3	8.1	13.2	7.8	6.8	3.7	0.0
16	3.0	5.7	3.3	1.3	4.7	2.0	0.7	2.0	3.0	13.7	24.7	7.0	8.7	9.7	7.7	3.0	0.0
17	4.8	4.8	3.7	1.7	3.7	1.0	0.7	2.7	2.0	13.3	26.2	7.5	5.4	7.8	11.2	3.4	0.0
18	3.7	7.5	2.4	0.7	1.4	0.7	2.7	1.7	5.1	12.2	27.8	6.1	8.8	7.1	8.5	3.7	0.0
19	5.4	4.1	2.4	0.7	0.7	1.7	1.4	4.4	6.4	12.5	22.4	10.2	6.4	8.8	6.4	6.1	0.0
20	5.8	5.8	2.1	1.0	1.0	1.7	2.7	4.1	7.2	11.7	23.4	9.3	7.9	7.2	5.5	3.4	0.0
21	8.0	5.5	3.1	2.8	0.7	0.3	1.7	3.8	7.6	13.1	22.8	11.4	5.2	4.8	5.9	3.1	0.0
22	7.3	4.5	3.1	1.0	0.3	3.5	1.0	4.2	9.1	12.2	24.1	8.0	4.9	5.9	4.9	5.6	0.0
23	7.7	4.9	3.8	1.0	0.3	1.4	1.4	5.9	8.0	11.9	22.7	10.1	5.6	6.3	5.6	3.1	0.0
24	7.4	7.0	1.4	1.1	2.8	1.8	2.5	4.6	6.7	10.9	21.1	13.7	8.1	4.2	2.8	4.2	0.0
All	4.9	5.1	2.6	3.1	3.2	2.2	2.5	3.5	6.6	13.4	21.5	9.9	8.0	5.5	4.6	3.3	0.0

Table 2-23. Wind Direction Frequency (%) by Hour of Day, December 1979 - November 1980, 10 m Level at Site 2, Tract C-a

Hr. of Day	WIND DIRECTION																
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Calm
1	2.8	0.9	2.8	1.4	0.9	2.8	1.8	3.2	6.0	12.0	6.1	16.6	18.4	7.8	4.1	2.3	0.0
2	4.2	0.9	2.8	2.3	1.4	2.3	4.2	3.7	6.9	11.1	15.3	19.0	14.4	4.6	5.1	1.4	0.5
3	3.2	1.9	1.4	0.9	1.4	2.3	1.9	2.3	5.1	13.0	16.7	17.6	14.4	6.9	5.1	5.6	0.5
4	2.8	2.3	1.4	0.9	0.9	2.8	3.3	3.3	7.4	13.5	13.0	17.7	15.3	7.4	4.2	3.3	0.5
5	4.2	2.8	0.5	2.3	0.5	1.4	3.3	4.2	7.9	15.8	13.0	12.6	21.4	6.0	3.3	0.9	0.0
6	5.1	3.3	0.9	1.9	0.5	1.4	2.8	4.7	9.8	18.6	14.0	10.2	14.0	3.3	6.0	3.3	0.0
7	3.3	4.2	5.1	2.8	4.7	2.3	4.2	5.1	12.6	16.7	11.6	9.3	6.0	3.7	3.7	4.7	0.0
8	5.6	6.0	3.3	5.6	6.5	4.7	6.5	4.7	10.2	19.1	8.4	6.0	7.4	0.5	2.3	3.3	0.0
9	5.4	3.1	4.5	4.9	8.5	6.3	4.5	3.1	9.4	17.5	11.2	9.4	7.2	1.8	1.3	1.8	0.0
10	4.0	2.2	4.5	7.6	6.7	6.3	3.1	2.7	8.5	14.7	17.0	8.0	8.9	2.7	1.3	1.8	0.0
11	6.3	3.6	4.5	5.4	3.6	2.2	2.7	4.0	4.5	17.9	17.4	9.4	9.8	4.5	1.3	3.1	0.0
12	4.0	4.9	3.1	3.1	4.9	1.3	2.7	2.2	4.0	22.6	16.8	11.1	11.5	3.5	2.7	1.8	0.0
13	5.8	4.0	3.1	2.2	1.3	0.9	2.2	2.2	4.4	21.7	15.0	12.8	10.6	7.1	3.5	3.1	0.0
14	3.9	3.9	2.6	1.8	1.8	2.6	0.9	4.4	4.4	17.5	15.8	10.5	14.5	9.2	3.5	2.6	0.0
15	3.5	4.0	4.4	1.8	3.5	1.3	0.0	1.8	5.7	18.1	18.1	6.2	14.1	11.0	3.1	3.5	0.0
16	4.3	3.9	3.4	3.4	2.6	1.7	0.4	3.0	3.9	20.7	19.4	5.2	7.8	12.5	3.9	3.9	0.0
17	6.6	4.4	3.5	3.1	2.2	0.9	1.3	1.8	5.7	19.4	20.3	6.2	7.9	11.5	4.4	0.9	0.0
18	6.6	3.9	2.6	0.9	0.4	1.3	2.2	2.6	5.3	24.1	18.4	5.7	7.9	12.7	1.8	3.5	0.0
19	3.5	3.5	2.6	0.9	0.9	1.8	1.8	2.2	8.4	17.6	18.5	9.3	14.5	6.6	4.8	3.1	0.0
20	3.1	1.8	0.9	1.8	1.8	0.0	2.2	3.1	5.4	17.9	18.4	14.8	15.2	7.6	3.1	2.7	0.0
21	6.4	1.4	1.4	0.9	0.9	0.0	1.8	4.1	5.9	15.9	17.3	19.1	13.6	6.8	2.7	1.8	0.0
22	3.7	2.8	2.8	1.4	2.3	1.8	1.8	4.1	6.0	12.9	14.7	15.7	18.0	6.9	2.3	2.8	0.0
23	4.1	3.2	1.4	0.9	1.4	0.5	4.6	1.8	7.8	12.8	18.8	17.4	12.8	5.0	3.2	4.1	0.0
24	4.6	2.8	1.4	0.5	1.9	0.9	1.9	4.6	7.4	8.8	21.3	18.5	14.8	3.7	3.7	3.2	0.0
All	4.5	3.2	2.7	2.4	2.6	2.1	2.6	3.3	6.7	16.7	16.1	11.9	12.5	6.4	3.4	2.8	0.1

Table 2-24. Wind Direction Frequency (%) by Hour of Day, December 1979 - November 1980, 10 m Level at Site 3, Tract C-a

Hr. of Day	WIND DIRECTION																
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Calm
1	0.4	0.4	0.4	2.6	2.9	0.4	1.1	0.7	1.1	2.9	4.0	9.9	65.0	5.8	1.1	1.5	0.0
2	0.0	1.8	2.2	1.5	1.5	0.7	0.7	2.2	2.6	2.2	1.1	10.6	67.0	4.4	0.4	1.1	0.0
3	1.5	0.7	1.5	2.6	0.7	0.4	0.4	1.1	0.7	1.8	2.2	15.1	68.4	2.2	0.7	0.0	0.0
4	0.4	1.1	0.0	1.1	2.2	1.1	0.0	0.4	0.7	2.6	2.2	8.5	74.5	2.6	1.5	1.1	0.0
5	0.0	1.1	0.4	1.1	1.5	1.1	0.7	1.1	1.1	1.1	3.0	8.5	72.0	3.0	2.2	1.1	0.0
6	3.4	1.5	2.6	1.5	1.5	0.4	1.1	1.1	2.2	2.6	3.0	10.1	57.3	6.4	3.4	1.9	0.0
7	2.6	3.0	4.5	9.3	5.9	3.7	2.2	2.6	3.0	5.9	4.8	11.5	32.7	3.0	1.9	3.3	0.0
8	1.5	2.6	5.9	16.0	15.6	2.6	3.7	0.7	4.8	5.6	11.2	11.5	12.6	1.9	1.9	1.9	0.0
9	1.8	2.5	7.9	16.2	16.5	4.3	3.6	4.0	2.9	6.1	12.2	8.3	6.8	2.5	2.2	2.2	0.0
10	2.5	4.3	5.7	18.4	13.1	3.2	1.4	2.5	2.1	5.7	16.7	12.1	8.2	2.1	1.8	0.4	0.0
11	2.5	3.9	5.6	9.5	10.9	2.5	1.1	2.1	3.5	4.2	20.7	17.9	10.5	2.8	0.4	2.1	0.0
12	1.4	4.9	5.3	7.4	9.9	2.1	0.7	2.1	2.8	2.8	26.1	12.0	14.8	3.9	2.1	1.8	0.0
13	2.5	4.2	4.2	6.7	6.3	1.1	0.4	2.5	3.2	4.6	22.1	13.0	16.5	6.3	2.8	3.9	0.0
14	1.7	3.1	5.2	8.7	4.5	1.7	0.7	1.7	1.7	3.1	22.5	17.3	20.8	2.8	2.8	1.7	0.0
15	3.1	3.1	4.9	7.7	5.2	2.8	0.3	0.3	2.4	3.1	24.0	14.6	19.9	5.2	1.4	1.7	0.0
16	1.4	4.1	6.2	8.6	5.8	0.3	0.0	1.7	2.7	3.8	25.4	12.4	15.8	7.6	1.4	2.7	0.0
17	2.5	4.2	6.0	2.8	1.8	3.2	1.8	1.4	2.8	4.2	23.7	14.5	14.8	9.5	3.2	3.5	0.0
18	3.2	3.5	3.9	2.5	1.4	0.0	1.4	1.8	1.8	3.9	16.5	19.4	24.6	9.5	3.5	3.2	0.0
19	3.5	1.8	1.8	4.2	0.7	0.7	1.4	1.4	1.8	1.1	7.4	19.1	46.3	6.4	1.1	1.4	0.0
20	1.8	2.5	3.9	1.4	0.7	0.7	1.1	1.4	1.4	1.4	2.5	14.3	61.8	2.9	0.7	1.4	0.0
21	2.5	1.1	3.2	1.4	1.4	1.1	0.7	1.8	1.8	2.2	3.2	9.4	61.9	4.7	2.2	0.7	0.7
22	3.3	1.1	1.5	1.5	1.5	0.4	0.4	1.5	2.2	2.5	4.4	9.1	62.9	6.2	1.1	0.7	0.0
23	2.2	1.5	1.5	2.5	0.7	1.5	0.4	1.1	1.5	1.1	4.7	10.2	61.8	5.8	0.7	2.9	0.0
24	1.5	0.7	2.6	0.0	0.7	1.8	1.1	1.1	1.5	2.9	2.2	9.1	66.4	4.4	2.2	1.8	0.0
All	2.0	2.5	3.6	5.7	4.7	1.6	1.1	1.6	2.2	3.2	11.3	12.5	39.8	4.7	1.8	1.8	0.0

D. Precipitation

1. Objectives

Precipitation is recorded to provide data on the moisture availability for plant growth and revegetation .

2. Methods

The methods followed for collection of these data were described in RBOSC MDP Report 2 and are not repeated herein.

3. Results and Discussion

Precipitation data from the several measuring methods for the period June 1979-November 1980 are included in the data appendix (Appendix 2-2.3). Snow depth measurements taken during the current year are presented in Appendix 2-2.4. There is a significant difference in the reported precipitation between the type of gauges installed at each site; the weighing bucket gauges generally recording relatively higher precipitation amounts than the tipping bucket gauges. The wedge gauge data generally fall between the results from the other two guage types.

Table 2-25 presents the monthly, seasonal and annual precipitation at Sites 1, 2 and 3 for the current year. The table is compiled from data which are collected by tipping bucket gauges, weighing bucket gauges, and wedge gauges. Precipitation measured at the three sites by a total of eight gauges during the current year ranged from 9.45 to 13.26 inches. Although the natural variability of precipitation is high in semi-arid regions, a substantial part of the range in values is thought to be due to different exposures and capture efficiencies of the gauges. Inspection of Table 2-25 reveals that the variability of precipitation on an annual basis among the three sites (located several miles apart) for one type of precipitation gauge does not exceed 1.25 inches, whereas the variability of precipitation among the gauges at one site (located tens of feet apart), in some cases exceeded 4 inches.

Table 2-25. Monthly, Seasonal, and Annual Precipitation (inches) at Sites 1, 2, and 3 from available Tipping Bucket Gauge, Weighing Bucket Gauge, and Wedge Gauge Data at Tract C-a for the period December 1979 - November 1980

	Site 1			Site 2			Site 3	
Month	Tipping Bucket Gauge	Weighing Bucket Gauge	Wedge Gauge	Tipping Bucket Gauge	Weighing Bucket Gauge	Wedge Gauge	Tipping Bucket Gauge	Wedge Gauge
December	0.21	0.45	0.42	0.22	0.47	0.46	0.21	0.39
January	0.84	0.73	1.10	0.37	0.85	0.83	0.54	0.77
February	0.85	1.32	1.12	0.84	1.23	0.96	0.69	0.79
March	1.33	2.01	1.77	1.49	1.70	1.68	1.58	1.92
April	1.08	1.21	1.16	0.22	1.06	0.95	0.92	1.36
May	1.42	2.03	2.06	0.71	2.20	2.38	1.23	1.68
June	0.06	0.06	0.06	0.00	0.00	0.00	0.00	0.00
July	1.00	1.19	1.22	1.02	1.14	1.04	1.18	1.18
August	1.69	1.31	1.97	1.56	1.80	1.84	2.34	2.25
September	0.28	0.41	0.68	0.52	0.46	0.64	0.55	0.63
October	0.65	0.90	1.28	0.96	1.13	1.16	0.66	1.00
November	0.04	0.21	0.42	0.29	0.44	0.44	0.40	0.37
Seasonal								
Winter (Dec, Jan, Feb)	1.90	2.50	2.64	1.43	2.55	2.25	1.44	1.95
Spring (Mar, Apr, May)	3.83	5.25	4.99	2.42	4.96	5.01	3.73	4.96
Summer (Jun, Jul, Aug)	2.75	2.56	3.25	2.58	2.94	2.88	3.52	3.43
Fall (Sep, Oct, Nov)	0.97	1.52	2.38	1.77	2.03	2.24	1.61	2.00
Annual	9.45	11.83	13.26	8.20	12.48	12.38	10.30	12.34

The weighing bucket gauges are thought to produce the most representative precipitation data, due to a better exposure and the improvement in winter capture efficiency through the use of snow shields. The tipping bucket gauges have historically recorded lower amounts of precipitation (RBOSC MDP Monitoring Report 5) than other gauges, which may be due to a less efficient capture and measurement technique.

Table 2-26 presents the results of the precipitation measurements collected onsite over the last three years. Based on this record, the 1978-79 reporting period was the wettest year. The best estimate of total precipitation over the past three years, based on data from the weighing bucket gauges, indicates that between 11 and 12 inches of precipitation fell during the 1977-78 reporting period, between 14 and 15 inches fell during 1978-79, and approximately 12 inches fell during the current year.

The wettest month during the current year was May, when close to 20 percent of the total annual precipitation fell. Although May was the wettest month, June turned out to be the driest month. No precipitation was recorded at Sites 2 and 3 during June, and only 0.06 inch at Site 1. This precipitation pattern has occurred during each of the past three years, and probably reflects the northward movement of the preferred storm track in early summer.

Spring was the wettest season, with 35-40 percent of the annual precipitation, while fall was the driest season with approximately 15 percent of the annual total. Spring was also the wettest season during the earlier years.

E. Solar Radiation

1. Objective

Solar radiation is monitored to acquire a data base useful in interpreting air quality data.

2. Methods

The methods followed for collection of these data were described in RBOSC MDP Monitoring Report 4 and are not repeated herein.

Table 2-26. Summary of Precipitation Measurements During the Last Three Years at Tract C-a

	December 1977-November 1978			December 1978-November 1979			December 1979-November 1980		
	Site 1	Site 2	Site 3	Site 1	Site 2	Site 3	Site 1	Site 2	Site 3
Tipping Bucket Gauge									
Winter	--	--	--	0.98	1.16	1.44	1.90	1.43	1.44
Spring	--	--	3.33	3.66	3.33	3.95	3.83	2.42	3.73
Summer	--	1.29[1/]	1.58	2.38	2.23	1.71	2.65	2.58	3.52
Fall	1.63	1.88	--	2.93	2.02	2.15	0.98	1.77	1.61
Annual	--	--	--	9.95	8.74	9.25	9.35	8.20	10.30
Weighing Bucket Gauge									
Winter	3.3	2.83	NA	3.52	3.53	NA	2.50	2.55	NA
Spring	5.15	5.19		6.06	4.78		5.25	4.96	
Summer	--	1.14[1/]		2.17	2.58		2.56	2.94	
Fall	3.21	2.21[1/]		3.28	3.08		1.52	2.03	
Annual	--	11.37[1/]		15.03	13.97		11.83	12.48	
Wedge Gauge									
Winter	2.28	1.56	1.70	2.43	2.80	2.52	2.64	2.25	1.95
Spring	4.27	4.63	3.98	5.44	4.59	4.16	4.99	5.01	4.96
Summer	1.82	1.21	1.57	2.28	2.58	1.95	3.25	2.89	3.43
Fall	2.94	2.70	2.32	2.43	2.15	2.45	2.38	2.24	2.00
Annual	11.31	10.10	9.57	12.58	12.12	11.08	13.26	12.39	12.34

[1/] Partial data only

3. Results and Discussion

The maximum hourly solar radiation recorded at the tract during the current year was 1.56 langleys/min.

2.3 CLIMATOLOGY

This section presents a description of the general climatology of the region in which Tract C-a is located.

1. Objectives

It is the intent to establish a climatology by comparing meteorological data collected from three sites surrounding the study area (defined as "onsite") with both short-term and long-term climatic data available from other meteorological stations in the region. The rugged topography of western Colorado causes variations in climate within short distances, and caution must be used when applying climatic generalizations to the whole area. Ideally, the most accurate way of characterizing the climatology of Tract C-a is to develop a long-term meteorological data base from meteorological data gathered onsite. The available onsite meteorological data base of five years cannot be construed as being representative of the long-term climatic conditions in the tract area. However, the onsite data can be compared with similar short-term and long-term data in the region to identify site-specific climatic conditions due to elevation, exposure, and the orientation of mountain ranges and valleys.

2. Methods

The methods followed for collection of climatological data were described in RBOSC MDP Monitoring Report 3 and are not repeated herein.

3. Results and Discussion

Figure 2-23 presents the sources of climatological data in the northwest section of the State of Colorado, where Tract C-a is located at an average elevation of approximately 7000 feet above MSL. The weather station closest to the tract is Little Hills, located 15 miles to the northeast of the study area at an elevation of 6140 feet. The Meeker No. 2 station is located about 30 miles to the east-northeast at an elevation of 6350 feet. The Rangely station is located about 20 miles to the west-northwest at an elevation of 5220 feet. Grand Junction, at an elevation of 4843 feet, is about 60 miles south of the site. All of

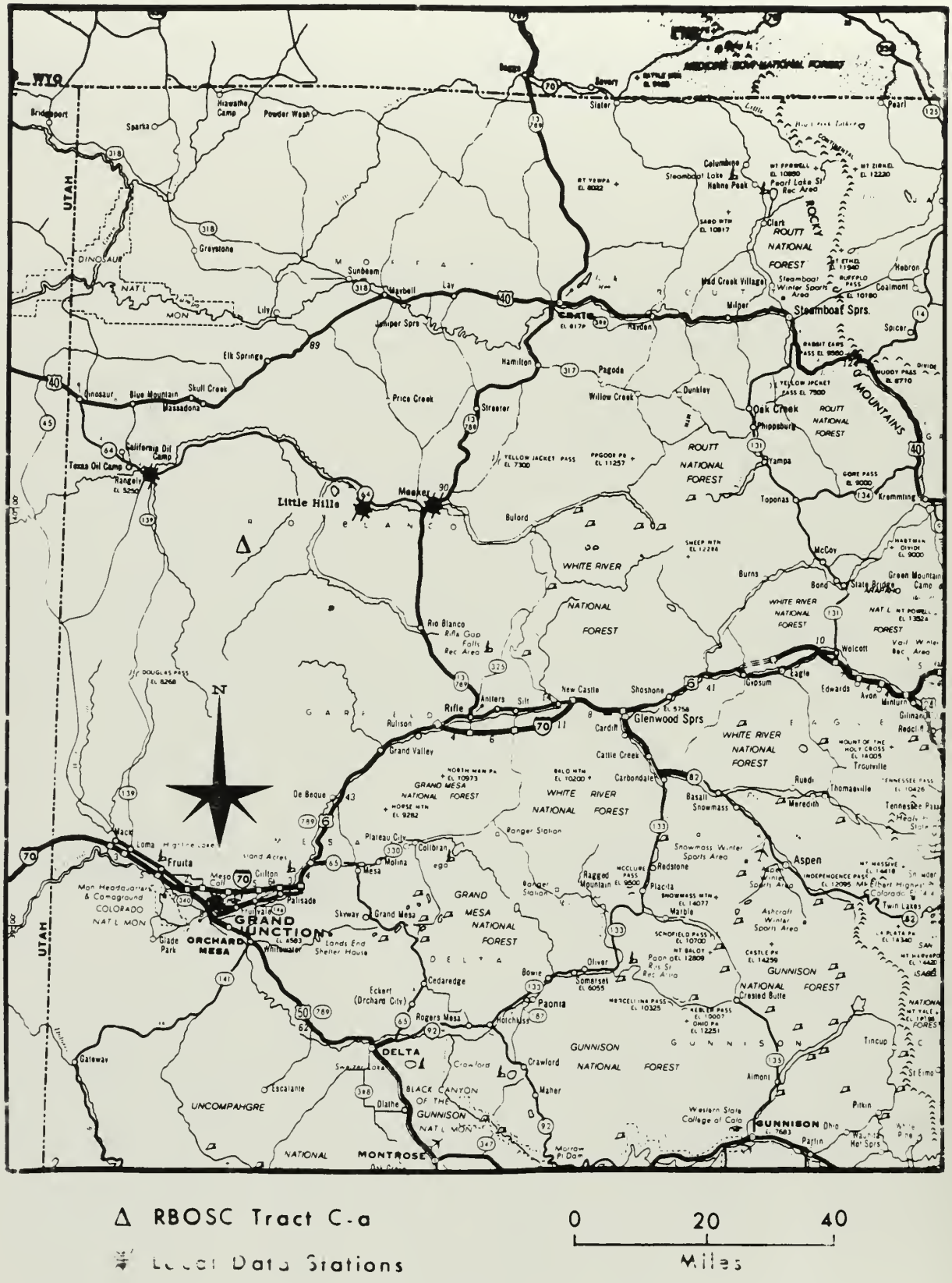

Figure 2-23. Map of Northwest Colorado Showing the Rio Blanco Region

these stations monitor temperature and precipitation. At Grand Junction other parameters are measured as well.

The following is a discussion of the climatology of the area and the influences of the topography on the general meteorological and climatic conditions in the area. It has been extracted from the Baseline Report (RBOSP 1977):

> The Tract C-a area is surrounded by high mountains. As a result, many migratory low pressure systems are deflected around the region. Stationary high-pressure cells often persist for several days, their passage blocked by the Continental Divide east of Tract C-a. As a result, there is a high frequency of clear sunny days with light winds and large diurnal temperature changes. Gradient winds are generally westerly, existing throughout the year, except when interrupted by the passage of frontal systems. Precipitation measurements indicate relatively low annual accumulations such as those of semi-arid steppe regions. In addition, the data indicate a high degree of temporal and spatial variability in this area, which is to be expected given the rough terrain with its variations in elevation and exposure. The infrequent occurrences of precipitation, fog, and small light-scattering airborne dust have produced excellent visibility, in general, for the Tract C-a area.
>
> Local topography within the Tract C-a area has a much more pronounced effect on surface flows than the macroscale processes. Specific air movements produced by local conditions are often different from those expected from the major gradient flow. There is a tendency for wind velocities to be lowest at sunrise, when there is little vertical thermal mixing and the lower surface air does not couple with the more freely moving upper air. Conversely, velocities of local winds are greatest in the early afternoon hours when the air exhibits its greatest tendency to move vertically due to terrestrial heating, and couples with the faster air moving above it.
>
> In the absence of strong gradient winds, the local terrain produces special meteorological conditions. During warm afternoon hours, the laterally constricted, but vertically expanding, air tends to flow up the valley. This air motion probably develops simultaneously with anabatic (upslope) winds which result from a greater

heating of the valley side than the valley floor. At night, the reverse process occurs with the cold, dense air at higher elevations draining into the depressions. The greater radiative heat loss affecting the higher elevations (especially if they are snow covered) cools the air immediately adjacent to the surface, and this air sinks into the valley. Downward flowing cold air set in motion by this effect forms downslope winds leading to an accumulation of cold, dense, stable air in the valley bottom.

The high Cathedral Bluffs to the west of Tract C-a and the deep gulches to the east effectively channel surface winds, and thereby decouple the upper level flows from the surface flows much of the time. Several studies have shown that airflow within the canyons of the Piceance Creek and Yellow Creek Basins is influenced by drainage winds in their respective channels, whereas winds measured atop the ridge-like portions of the basin closely follow the gradient wind regime. It can be inferred that these drainage winds occur in conjunction with stronger temperature inversions within the valley than at the ridge regions.

Meteorological data collected at the site during the current year can be compared to data for the same period from Grand Junction and to the Grand Junction long-term averages for the period 1941-1970.

Table 2-27 presents the monthly departures from normal for Grand Junction mean temperature, total precipitation, mean relative humidity, and mean wind speed during the current year. The departure during the current year of the mean annual temperature at Grand Junction from the long term average was +0.8 F. The Grand Junction mean annual temperature exceeded the RBOSC Site 1 mean during the current year by 8.0 F. The annual precipitation during the current year at Grand Junction was 1.76 inches above the long-term average, while the Site 1 precipitation was 1.66 inches above the Grand Junction total for the year. The Site 1 mean wind speed was 1.1 mph lower than the Grand Junction mean wind speed for the current year.

Table 2-27 indicates that Grand Junction data compares rather poorly with onsite data. The mean annual temperature decrease of 8 F and the total annual

Table 2-27. Monthly Departures from the Long-term Means for the Data Period December 1979 - November 1980 for Grand Junction and Comparison with Tract C-a Annual Values

		Temperature (F)			Precipitation (inches)			Relative Humidity[1] (%)			Mean Wind Speed (mph)		
	Month	Long Term Mean	1979-1980 Mean	Departure From Mean	Long Term Mean	1979-1980 Mean	Departure From Mean	Long Term Mean	1979-1980 Mean	Departure From Mean	Long Term Mean	1979-1980 Mean	Departure From Mean
Grand Junction	December	29.5	26.9	- 2.6	0.55	0.27	- 0.28	67	74	+ 7	5.9	6.2	+ 0.3
	January	26.6	32.6	+ 6.0	0.64	0.57	- 0.07	70	74	+ 4	5.6	7.3	+ 1.7
	February	33.6	39.2	+ 5.6	0.01	1.10	+ 0.49	56	67	+ 11	6.7	7.1	+ 0.7
	March	41.2	40.9	- 0.3	0.75	1.77	+ 1.02	44	61	+ 17	8.4	9.1	+ 0.7
	April	51.7	51.4	- 0.3	0.79	0.53	- 0.26	40	42	+ 2	9.7	9.8	+ 0.1
	May	62.2	59.1	- 3.1	0.63	1.17	+ 0.54	34	49	+ 15	9.6	9.5	- 0.1
	June	71.3	74.0	- 2.7	0.55	T	- 0.55	31	19	- 12	9.8	9.7	- 0.1
	July	78.7	78.6	- 0.1	0.46	0.96	+ 0.50	33	34	+ 1	9.3	9.3	0.0
	August	75.4	75.3	- 0.1	1.05	1.39	- 0.34	35	34	- 1	9.0	9.4	+ 0.4
	September	67.2	67.9	+ 0.7	0.84	0.58	- 0.26	38	33	- 5	9.0	8.8	- 0.2
	October	54.9	53.8	- 1.1	0.93	1.31	+ 0.38	44	42	- 2	7.9	7.9	0.0
	November	39.8	42.3	+ 2.5	0.61	0.52	- 0.09	57	51	- 6	6.6	6.8	+ 0.2
	Annual	52.7	53.5	+ 0.8	8.41	10.17	+ 1.76	46	48	+ 2	8.1	8.4	- 0.3
RBOSC Site 1		NA	45.5	NA	NA	11.83	NA	NA	NA	NA	NA	7.3	NA
RBOSC departure from Grand Junction		NA	- 8.0	NA	NA	+ 1.66	NA	NA	NA	NA	NA	- 1.1	NA
RBOSC Site 1 5-yr Mean[2]		44.4			12.72[3]				NA		7.4		

[1] Based on daily averages of four readings

[2] The RBOSC 5-year mean data does not constitute a long term mean

[3] Based on a 3-year data record

precipitation increase of 2 inches from Grand Junction to Tract C-a has been relatively constant for the last two years (RBOSC MDP Monitoring Report 5). Consequently, Grand Junction data should be used very cautiously in describing the climatology of the tract. This climatological difference between Site 1 and Grand Junction can also be seen in the frost-free period, which was 48 days longer during 1980 at Grand Junction.

This difference is not unexpected, since Grand Junction is located in a valley approximately 2500 feet lower than Site 1. In fact, an estimate can be made of the temperature that would be expected if the Grand Junction station was at the same altitude as Site 1, by using the NACA Standard Atmosphere lapse rate for 40°N latitude of 3.57 F/1000 ft (Hess 1959). Using this approximation, the Grand Junction mean annual temperature would be reduced by 8.9 F. Thus, the large discrepancy in mean annual temperatures between the site and Grand Junction can be accounted for simply by the altitude differential. However, it should be emphasized that topographic influences can also be large; whereas the standard lapse rate indicates that Site 3 should have a mean annual temperature 2.8 F higher than Site 1, the actual mean annual Site 3 temperature for the current year is 2.2 F lower than Site 1.

Table 2-28 presents monthly temperature data collected during the current year from Site 1, three surrounding climatological stations (Rangely, Meeker No. 2, and Little Hills), and Grand Junction. The table shows that Grand Junction temperature data are not very representative of at least part of Rio Blanco County. The mean monthly and annual temperatures at the three climatological stations in the county agree well with the onsite data, especially considering the elevation and topographic differences among the sites. A major difference between Site 1 and the other stations is evident, however, in the average temperature range compared to the other local stations. This is due primarily to the relative location of the instruments. All climatological stations measure temperature 6 feet above the ground in a standard weather shelter, whereas the Site 1 temperature sensor is located at 10 m (33 ft.). Since temperature changes in the lower layers of the atmosphere result from heat transfer from the ground surface, the diurnal temperature range will decrease with height above the ground. Thus, the reduced temperature range at Site 1 relative to the surrounding stations is largely due to the increased height of the temperature sensors at Site 1.

Table 2-28. Comparison of Monthly Temperature (F) in the Vicinity of Tract C-a for the Data Period December 1979 - November 1980

Month	Tract C-a Site 1			Little Hills			Meeker No. 2			Rangely			Grand Junction		
	Avg Max	Avg Min	Mean	Avg Max	Avg Min	Mean	Avg Max	Avg Min	Mean	Avg Max	Avg Min	Mean	Avg Max	Avg Min	Mean
December	36.5	26.8	32.2	40.3	3.0	21.7	37.9	9.4	23.7	34.9	4.8	19.9	36.5	17.2	26.9
January	30.0	18.1	23.5	37.9	11.4	24.7	37.8	15.4	26.6	32.6	12.0	22.3	39.8	25.4	32.6
February	35.6	24.8	30.0	43.7	14.4	29.1	42.8	18.1	30.5	40.0	13.0	26.5	49.3	29.1	39.2
March	34.7	22.6	28.8	45.9	18.0	32.0	45.2	20.7	33.0	49.7	22.9	36.3	51.5	30.3	40.9
April	47.7	32.9	40.5		M		58.1	27.2	42.7	63.6	30.0	46.8	65.8	36.9	51.4
May	54.1	39.9	47.1	64.7	32.0	48.4	65.0	35.9	50.5	68.6	41.5	55.1	72.0	46.1	59.1
June	71.4	55.2	64.0		M		82.1	41.6	61.9	87.4	46.6	67.0	90.9	57.1	74.0
July	76.6	61.3	69.1	87.9	45.4	66.7	82.5	50.0	68.1	91.9	54.2	73.1	94.1	63.0	78.6
August	73.6	56.8	65.5	82.5	40.3	61.4	83.4	46.3	64.9		M		90.0	60.5	75.3
September	67.6	53.1	60.4	74.6	31.8	53.2	76.3	39.3	57.8	77.8	41.5	59.7	83.0	51.9	67.9
October	53.2	38.8	46.0	62.8	20.5	41.7	63.3	28.1	45.7	64.3	30.5	47.4	67.4	40.1	53.8
November	44.1	32.4	37.9	49.7	9.6	29.7	51.2	20.9	36.1	50.5	19.2	34.9	54.2	30.4	42.3
Annual			45.5			M			45.1			M			53.5

M = missing data

Table 2-29 presents a comparison of Site 1 precipitation with data from surrounding stations for the current year. Monthly precipitation amounts at all of the stations vary widely due to the complex orographic influences of the region and the intermittent nature of precipitation in the region (particularly during the summer), but annual totals are reasonably close. Grand Junction had the lowest monthly precipitation totals of all stations, probably because of its protection by surrounding higher terrain.

Table 2-29. Comparison of Monthly Precipitation (inches) in the Vicinity of Tract C-a for the Data Period December 1979 - November 1980

Month	Tract C-a Site 1	Little Hills	Meeker No. 2	Rangely	Grand Junction
December	0.45	0.39	0.19	0.52	0.27
January	0.73	1.15	1.41	0.55	0.57
February	1.32	1.61	2.22	1.08	1.10
March	2.01	2.07	1.82	0.84	1.77
April	1.21	M	0.55	0.44	0.53
May	2.03	2.77	1.76	2.14	1.17
June	0.06	M	0.00	0.02	T
July	1.19	1.38	1.63	1.02	0.96
August	1.31	1.81	1.43	M	1.39
September	0.41	0.81	0.67	0.80	0.58
October	0.90	1.20	1.87	1.14	1.31
November	0.21	0.68	0.48	0.34	0.52
Annual	11.83	M	14.03	M	10.17

M = Missing Data

T = Trace of precipitation

2.4 QUALITY ASSURANCE AND DATA RECOVERY

The data summaries incorporated in the Appendices, with the exception of precipitation and particulate data, were prepared from data acquired by an automatic data acquisition system located on Tract C-a. The data are recorded both on magnetic tape and analog strip chart recorders. A comprehensive quality assurance program has been maintained to ensure the reliability and accuracy of the data. This program includes documentation by the site technician of all calibrations and system malfunctions, weekly zero and span calibrations of the air quality instrumentation, utilization of control charts onsite to detect problems in the weekly span calibrations, quarterly calibrations of the air quality instrumentation by both the internal technical staff and an independent auditing team, semi-annual calibrations of the meteorological instrumentation, and review of the analog and digital data by qualified analysts.

The air quality instruments are calibrated using pollutant sources traceable to National Bureau of Standards (NBS) standards. The carbon monoxide and the nitrogen oxide analyzers were calibrated using a known concentration of test gases which had been certified by the vendor. Calibration of the sulfur dioxide instrument was conducted with a permeation tube source using a Monitor Labs calibrator. The ozone analyzer is calibrated using the gas phase titration method.

Each instrument was tested at least once a week by inserting a zero pollutant concentration and at least one upscale concentration. These tests provided data on instrument drift and ensured that the instrument would respond to a detectable level of pollutant concentration in the ambient air.

The quarterly field calibrations were used to determine the accuracy of the instruments. No correction factors were required to adjust the data. Independent quarterly audits by an EPA contractor (Rockwell International) were used to check the internal calibration methods and were not used to adjust the data during this period. All of the audited instruments were within ±10 percent of the auditor's equipment, which conforms with EPA guidelines.

The air quality data include many hours where the concentration of some pollutants fell below the reliable threshold of detection of the instrument

(based on the manufacturer's specifications). When this occurred, a number equal to one-half the threshold value was substituted for the data point. This procedure is adopted from the EPA Quality Assurance Handbook, Air Pollution Measurement, Vol. 1. This applied to sulfur dioxide, hydrogen sulfide, nitrogen oxides and carbon monoxide data acquired through much of the data period.

The meteorological system is calibrated on a semi-annual basis. This includes routine replacement of all wind speed and wind direction sensors. No correction factors were required to adjust the data.

Data recoveries for all meteorological and air quality parameters collected by the onsite data acquisition system are presented in Tables 2-30 and 2-31.

The data recovery of all meteorological parameters met or exceeded the 75 percent level recommended by the EPA, with the exception of the dewpoint at Site 1 and the three parameters monitored at Site 2. The problem at Site 2 was caused by intermittent polling by the data acquisition system, which has since been corrected.

The data recovery of the air quality parameters at Site 1 met or exceeded the 75 percent criterion. The three parameters monitored at Site 3 during the entire year (O_3, H_2S, and SO_2) had a minimum data recovery of 70 percent.

Table 2-30. Annual Data Recovery (%) of Air Quality Parameters Monitored at Tract C-a for the Period December 1979-November 1980

Parameter	Data Recovery (%)
Site 1	
O_3	78
CO	79
NO	77
NO_x	77
H_2S	75
SO_2	79
Site 3	
O_3	72
CO	36[1/]
NO	65[1/]
NO_x	65[1/]
H_2S	70
SO_2	74

[1/] These instruments were installed at Site 3 during the year, so data recovery on an annual basis is misleading

Table 2-31. Annual Data Recovery (%) of Meteorology Parameters Monitored at Tract C-a for the Period December 1979-November 1980

Parameter	Data Recovery (%)
Site 1	
10 m wind speed	79
10 m wind direction	78
60 m wind speed	79
60 m wind direction	79
10 m temperature	79
60 m temperature	79
ΔT 60-10 m	79
dew point	72
solar radiation	79
Site 2	
10 m wind speed	61
10 m wind direction	61
10 m temperature	60
Site 3	
10 m wind speed	76
10 m wind direction	76
10 m temperature	75

2.5 VISIBILITY

Documentation of visibility in the Piceance Creek Basin is a cooperative study conducted by the Rio Blanco Oil Shale Company and the Cathedral Bluffs Oil Shale Company.

1. Objectives

The objectives of this program are to document the visibility in the area of the Piceance Creek Basin and identify trends or variations in visibility which may be evident during the monitoring program. The results of this program will provide visibility data against which past and future data may be compared and with which concurrent meteorological and air quality data may be incorporated for further evaluation and consideration.

2. Methods

Two methods are being employed in the to measure of basin-wide visibility during the spring and fall studies. A photometric method incorporates techniques identical to those utilized during the baseline study to calculate visual ranges, which were described in RBOSC MDP Monitoring Report 1. A second method uses a telephotometer to derive visual ranges. The results of the two methods will be compared after the telephotometer data have been reduced. Data are collected every sixth day from a centrally located shelter (Figure 2-24) during the spring and the fall.

3. Results and Discussion

This analysis, similar to the earlier studies in 1975-76, 1978, and 1979, is based only on the photometric data. Comparisons between the two methods will be made after reduction of the telephotometer data has been completed.

During the 1980 monitoring period, visual range measurements were made on 18 of the 20 scheduled days of photography over a five month period. Late snows prevented the spring monitoring program from beginning before May, which extended the sampling period into early July. The fall program was completed on

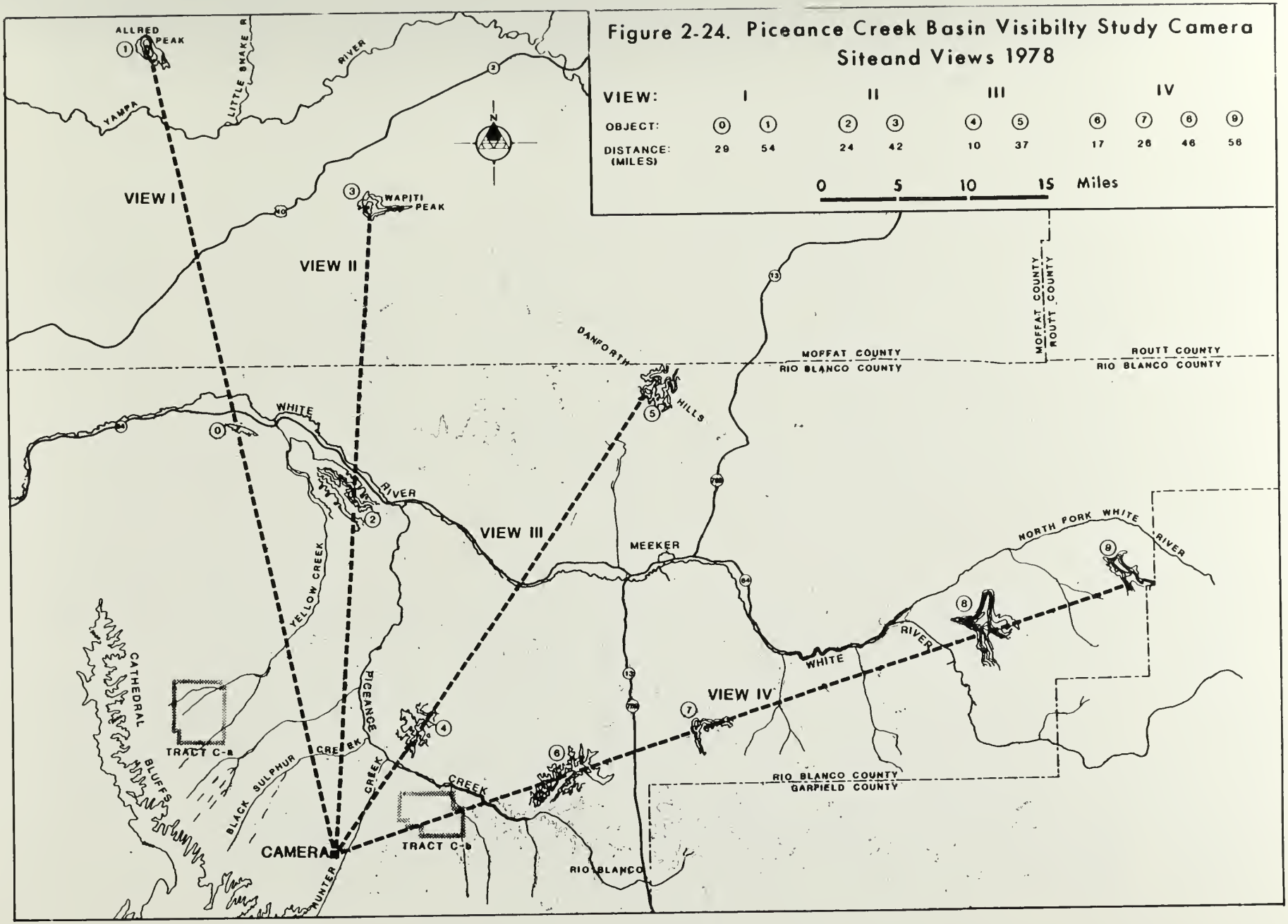
Figure 2-24. Piceance Creek Basin Visibilty Study Camera Siteand Views 1978
VIEW: I II III IV
OBJECT: 0 1 2 3 4 5 6 7 8 9
DISTANCE (MILES): 29 54 24 42 10 37 17 26 46 56
0 5 10 15 Miles
ALLRED PEAK
LITTLE SNAKE R
YAMPA
RIVER
WAPITI PEAK
VIEW I
VIEW II
VIEW III
VIEW IV
DANFORTH HILLS
MOFFAT COUNTY
ROUTT COUNTY
RIO BLANCO COUNTY
MOFFAT COUNTY
ROUTT COUNTY
RIO BLANCO COUNTY
WHITE RIVER
MEEKER
NORTH FORK WHITE RIVER
WHITE RIVER
YELLOW CREEK
PICEANCE CREEK
BLACK SULPHUR CREEK
CATHEDRAL BLUFFS
TRACT C-a
TRACT C-b
CAMERA
HUNTER CREEK
RIO BLANCO
RIO BLANCO COUNTY
GARFIELD COUNTY

schedule in October and November. Of a possible 560 scheduled visual range measurements, 481 valid measurements were obtained, for an 86 percent data recovery.

Measurements of visual range during the year were occasionally hampered by passing rain or snowshowers which restricted visibility and made photography of the views difficult. Accumulations of snow on some objects being photographed required adjustments to be made in their albedo (short-wave reflectivity). The resulting albedo for these objects was estimated using the original albedo of the object modified by the relative contribution of the snow. The albedo values used for the original objects' surfaces and for the additional snow cover were based on the spectral reflectance of snow and various soil types listed in the Handbook of Geophysics and Space Environments (Valley 1975).

Visual range measurements have now been taken over four periods which can be compared: Fall 1975 and Spring 1976, which represent the baseline period; and the Spring and Fall of 1978, 1979, and 1980, which represent the MDP period.

a. Evaluation of visual range on a daily basis - The computation of a daily mean visual range provides an indication of the prevailing visibility and conditions found in an area during the course of a day, unbiased by short-term or directional anomalies. Daily mean, maximum, and minimum visual ranges in the Piceance Creek Basin were calculated for each day of monitoring and the results are presented in Table 2-32.

The daily mean visual ranges obtained during 1980 were generally high and were most frequently between 70 and 80 miles, although daily mean visual range varied from 45 to 119 miles. The hourly visual ranges used to compute the daily mean visual ranges for the spring and fall monitoring periods are included in Appendices 2-6.1 and 2-6.3, respectively. A description of visual and meteorological conditions existing on the sampling days are presented as Site Log Sheets in Appendices 2-6.2 and 2-6.4.

Large fluctuations in the mean visual range between consecutive sampling days were common during 1980, with day-to-day variations ranging from 0 to 46 miles. Between May 16 and 22, 1980, for example, the mean visual range increased from

Table 2-32. Daily Mean Visual Range (Miles) Piceance Creek Basin, Colorado Spring and Fall, 1980

	Date	Mean Visual Range	Hourly Min./Max.
Spring			
	May 4, 1980	77	57/112
	10	68	45/115
	16	45	22/63
	22	74	49/103
	June 3, 1980	77	52/102
	9	94	75/119
	15	94	74/126
	21	77	61/120
	27	71	49/97
	July 3, 1980	93	68/120
Fall			
	October 1, 1980	106	83/161
	7	82	65/114
	13	57	17/76
	19	73	57/108
	November 6	119	69/161
	12	108	63/173
	18	103	54/176
	30	83	53/133

45 to 74 miles. However, between June 9 and 15, 1980, the mean visual range remained constant at 94 miles. The fluctuations exhibited in 1980 were about the same as comparable periods in the earlier studies. The average change between consecutive sampling days during the Spring and Fall of 1979 was 17 miles, compared with 18 miles during 1979, 16 miles during 1978, and 28 miles during the baseline period (1975-76).

The daily mean visual range is computed as an average of the visual ranges in each of four views (Figure 2-25). The increases or decreases in mean visual range between consecutive sampling days, evident in Table 2-32, were generally matched by similar increases or decreases in the visual range at each view. These fluctuations, shown in Figure 2-25, illustrate the similar response to changes in visibility which each view exhibited. The correlation between fluctuations in daily mean visual ranges among the views implies that the influences on visibility were widespread and generally uniform in the way they affected visibility.

b. Evaluation of visual range on a monthly basis - Monthly mean visual ranges were calculated from measurements obtained from all the views and hours during each month of monitoring. The monthly mean visual ranges obtained in the Piceance Creek Basin Area during the spring and fall monitoring periods are listed in Table 2-33. Values obtained during comparable periods in 1975-76, 1978, and 1979, have been included for review and comparison with the 1980 data.

Monthly mean visual ranges obtained during the four full months of monitoring in 1980 range from 67 miles in May to 103 miles in November. The values obtained in May and October were similar to visual range measured during the three previous years. The largest change in mean visual range occurred in November, when an increase of 30 miles was measured in comparison with the average of the two earlier MDP years (1978 and 1979). The mean visual range for November of 1980 is very similar to the original monitoring done during the baseline period (103 miles compared to 99 miles). The most likely reason for this increased visual range is the exceptionally warm, dry weather that occurred in the Piceance Creek Basin in November.

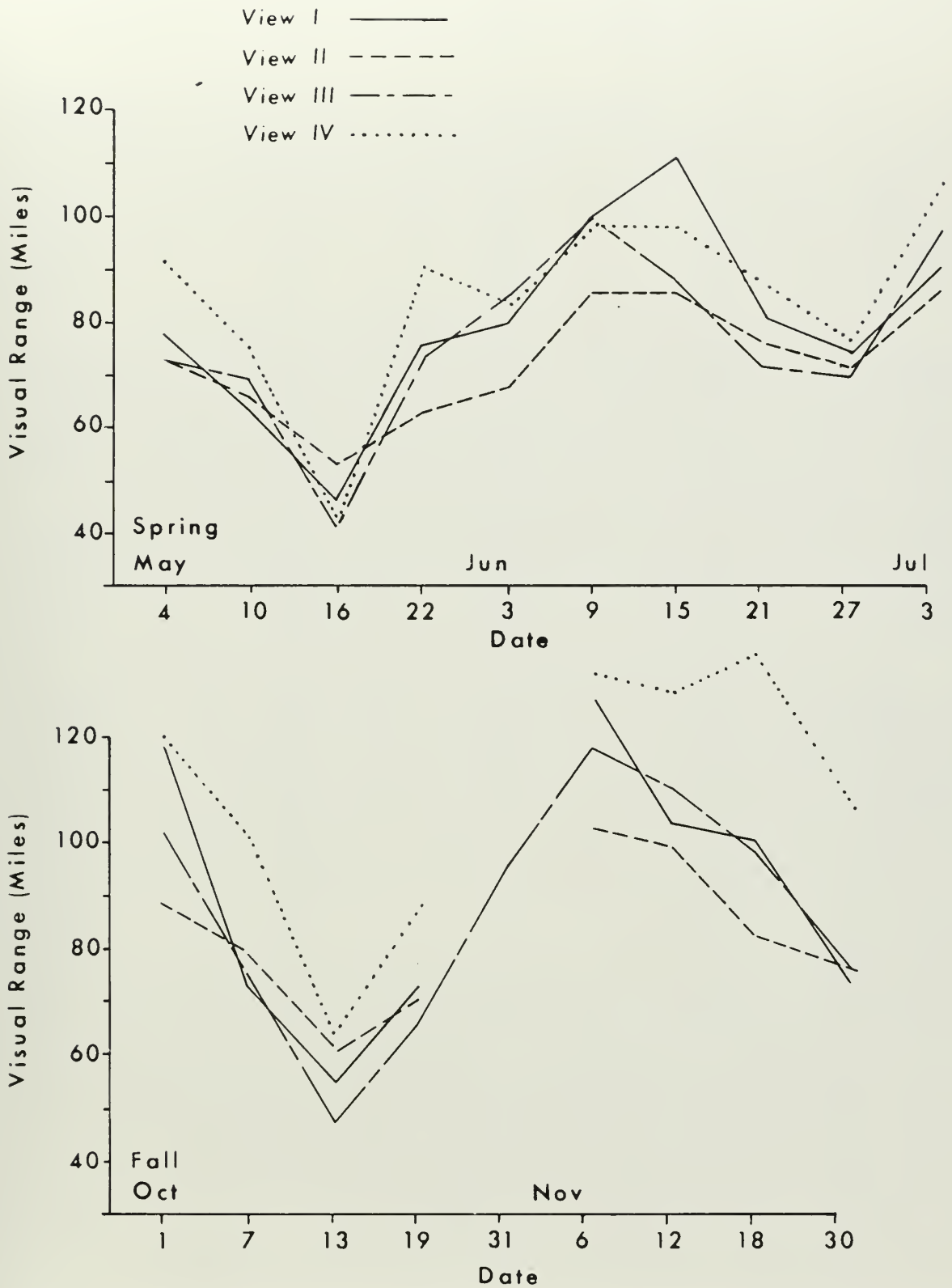

Figure 2-25. Daily Mean Visual Range For Each View, Spring and Fall 1980, Piceance Creek Basin, Colorado

Table 2-33. Monthly Composite Visual Range Comparison (Miles) During Spring and Fall for 1975-1976, 1978, 1979, and 1980, Piceance Creek Basin, Colorado

Month	Mean[1/]	Maximum	Minimum	Standard Deviation
April 1979[2/]	67	86	43	9.9
April 1978	83	142	21	21.1
April 1976	67	138	14	27.7
May 1980	67	115	22	18.7
May 1979	78	154	36	26.9
May 1978	74	132	17	20.5
May 1976	70	124	27	16.7
June 1980	83	126	49	16.2
June 1979[3/]	85	117	54	16.7
June 1976	71	117	45	14.8
October 1980	83	161	17	22.6
October 1979	89	137	50	17.2
October 1978	84	130	50	16.2
October 1975	89	144	44	24.6
November 1980	103	176	53	28.3
November 1979	77	132	25	25.1
November 1978[4/]	70	121	22	26.4
November 1975	99	149	24	29.0

[1/] Monthly means are based on approximately five days of photography per month

[2/] Values based on two full days and one partial day of photography

[3/] Values based on two full days of photography

[4/] Values based on one full day and three partial days of photography

This confirms earlier findings that the overriding controlling factor which has affected visibility in the Piceance Creek Basin to date are the meteorological conditions.

Hourly maximum and minimum visual range measurements for each month are also listed in Table 2-33. The absolute minimum and maximum visual ranges encountered during the three years of sampling were 14 and 149 miles in 1975-76, 17 and 142 miles in 1978, 25 and 154 miles in 1979, and 17 and 176 miles in 1980.

c. Evaluation of visual range on a seasonal basis - Visual range measurements were made from May to early July and in October and November 1980 to quantify and characterize the visibility of the area. The selection of these seasons for data collection was based on the results of the initial study (1975-76), which indicated that the seasonal mean visual range was at a minimum during the spring and at a maximum during the fall. Visibility data measured during these two seasons in 1980 are compared with data obtained during the three earlier years of record.

The visual ranges obtained within the Piceance Creek Basin during the two seasons in 1980 were generally high; the mean visual ranges were 78 miles during the spring and 93 miles during the fall. These and additional statistical descriptors are listed in Table 2-34 for each season and for the comparable seasons in 1978 and 1975-76. The data for 1975-76, however, includes three months per season, although the sampling frequency (once per six days) was identical.

During the Spring of 1980, 95 percent of the visual range measurements were greater than 45 miles and 50 percent were greater than 78 miles. This compares with fifth and fiftieth percentile visual ranges of 46 and 72 miles in the Spring of 1979, 43 and 81 miles in the Spring of 1978, and 39 and 67 miles in the Spring of 1976, respectively. The mean visual ranges during the fall have been higher than the spring in each of these sampling years. Ninety-five percent of the visual range measurements during the Fall of 1980 were greater than 55 miles; 50 percent were greater than 90 miles. This compares with fifth

Table 2-34. Seasonal Composite Visual Range Comparison (Miles During Spring and Fall for 1975-1976, 1978, 1979, and 1980, Piceance Creek Basin, Colorado

Season	Mean	Maximum	Minimum	Fifth Percentile	Standard Deviation
Spring 1980	78	126	22	45	19.0
Spring 1979	77	154	36	46	22.2
Spring 1978	79	142	17	43	21.2
Spring 1975-76	69	138	14	39	21.1
Fall 1980	93	176	17	55	27.6
Fall 1979	84	137	36	42	21.9
Fall 1978	80	130	22	43	20.5
Fall 1975-76	91	149	24	45	27.3

and fiftieth percentile ranges of 42 and 87 miles in the Spring of 1979, 43 and 82 miles in the Spring of 1978, and 45 and 92 miles during the Fall of 1975, respectively.

The seasonal composite visual range summary is shown for the spring and fall for each of the four years in Figures 2-26 through 2-29. The figures illustrate that there is a definite shift toward higher visual ranges from spring to fall in 1980, 1979, and 1975-76. A seasonal change is less apparent in 1978, although there is a lower frequency of low visual range data in the fall compared to the spring. These figures are reinforced by the data based on Table 2-34, which show that the change in the mean visual range from spring to fall was 15 miles in 1980, 7 miles in 1979, 22 miles in 1975-76, but only 1 mile in 1978.

Part of the reason that there was only a minimal seasonal shift in mean visual range for 1978 is apparent upon close inspection of Table 2-35. The hourly maximum visual ranges in the Fall of 1978 are much below the maximum for the other three years. Consequently, the absence of the shift in 1978 may be due only to the lack of one or two clear days -- it should also be noted that the data recovery for November 1978 was low, so the data base is smaller.

Table 2-35 shows the seasonal visual range summary for each view during all three years of record. The table indicates that the mean visual range data for the Spring of 1978, 1979, and 1980 are fairly similar for each of the four views. The baseline year (1975-76) in comparison had generally lower mean visual ranges in the spring. During the fall, however, the data from 1980 compares best with the baseline data, while 1978 and 1979 are similar. These seasonal and year-to-year variations are most likely due to changes in the meteorological conditions.

d. Evaluation of visual range on an annual basis - Visual range measurements made during 1980 were generally high with an annual mean visual range of 85 miles. This compares with an annual mean of 80 miles in 1979 and 79 miles during the first two years of study (Table 2-36). The range of values obtained was also quite high; visual ranges in 1980 varied from 17 miles to 176 miles. The distribution of these values is presented in Figure 2-30. Distributions for 1979, 1978, and 1975-76 are presented in Figures 2-31 through 2-33 for comparative purposes.

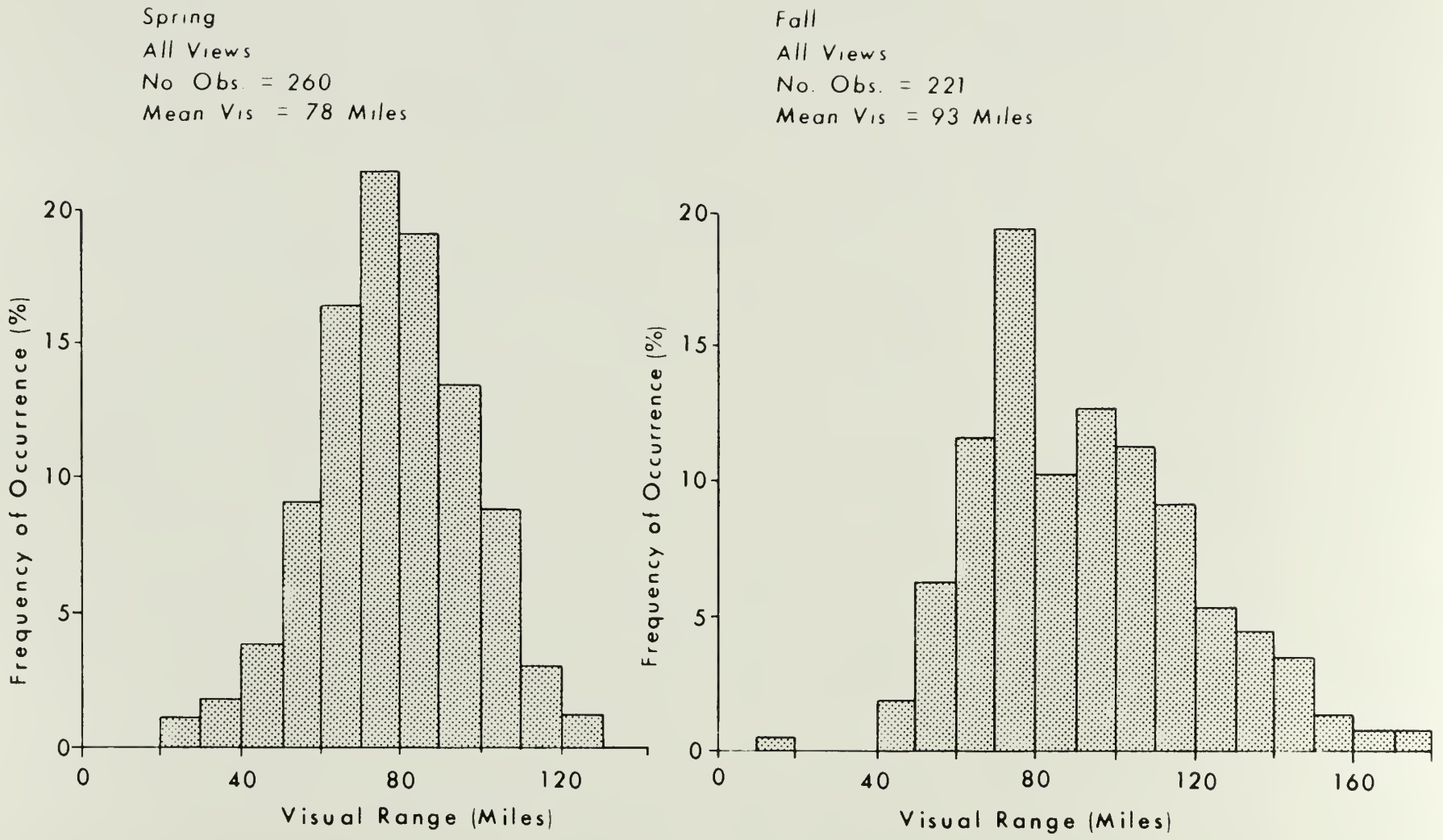

Figure 2-26. Seasonal Composite Distribution of Visual Range, Spring and Fall 1980, Piceance Creek Basin, Colorado

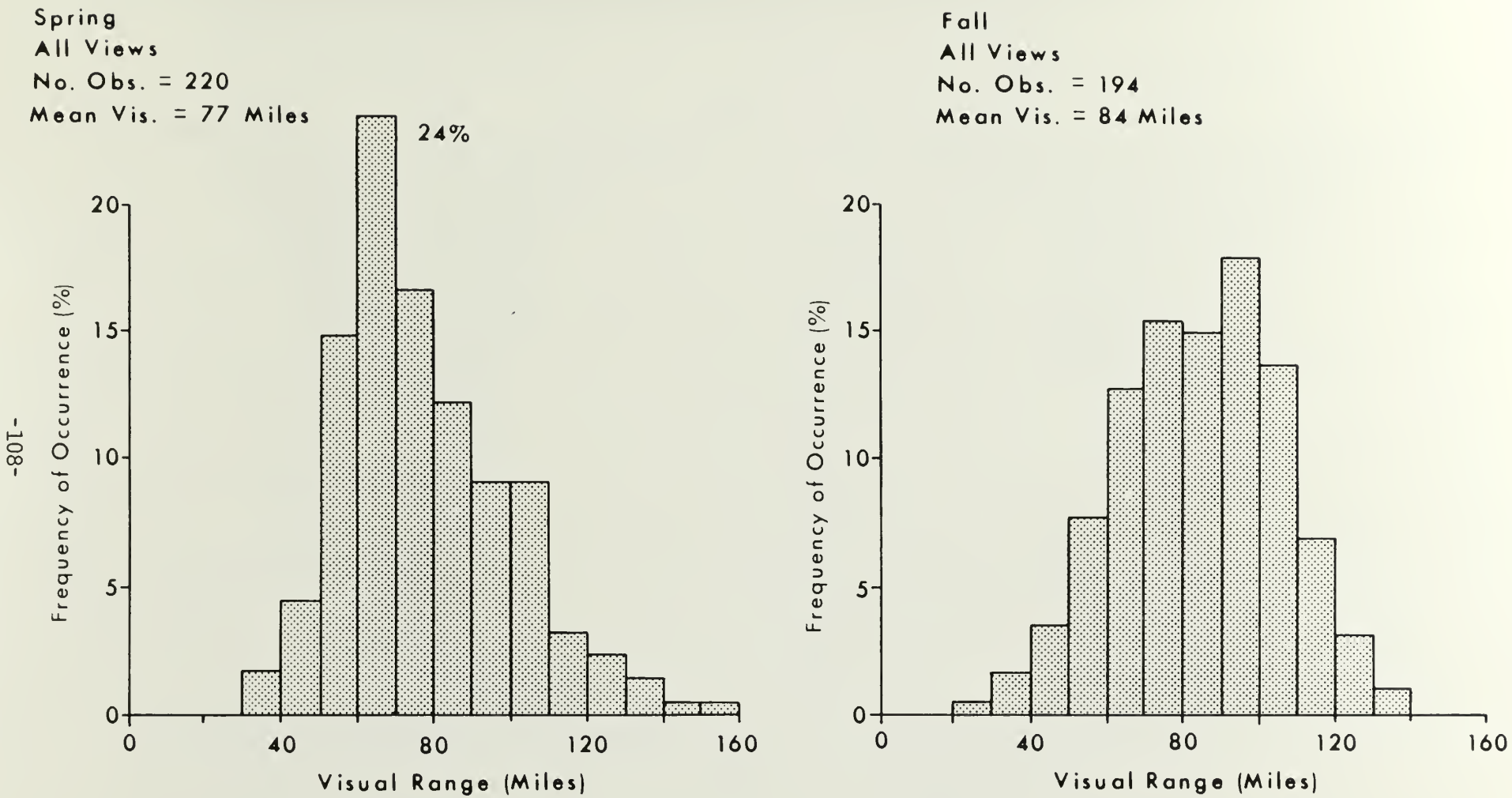

Figure 2-27. Seasonal Composite Distribution of Visual Range, Spring and Fall 1979, Piceance Creek Basin, Colorado

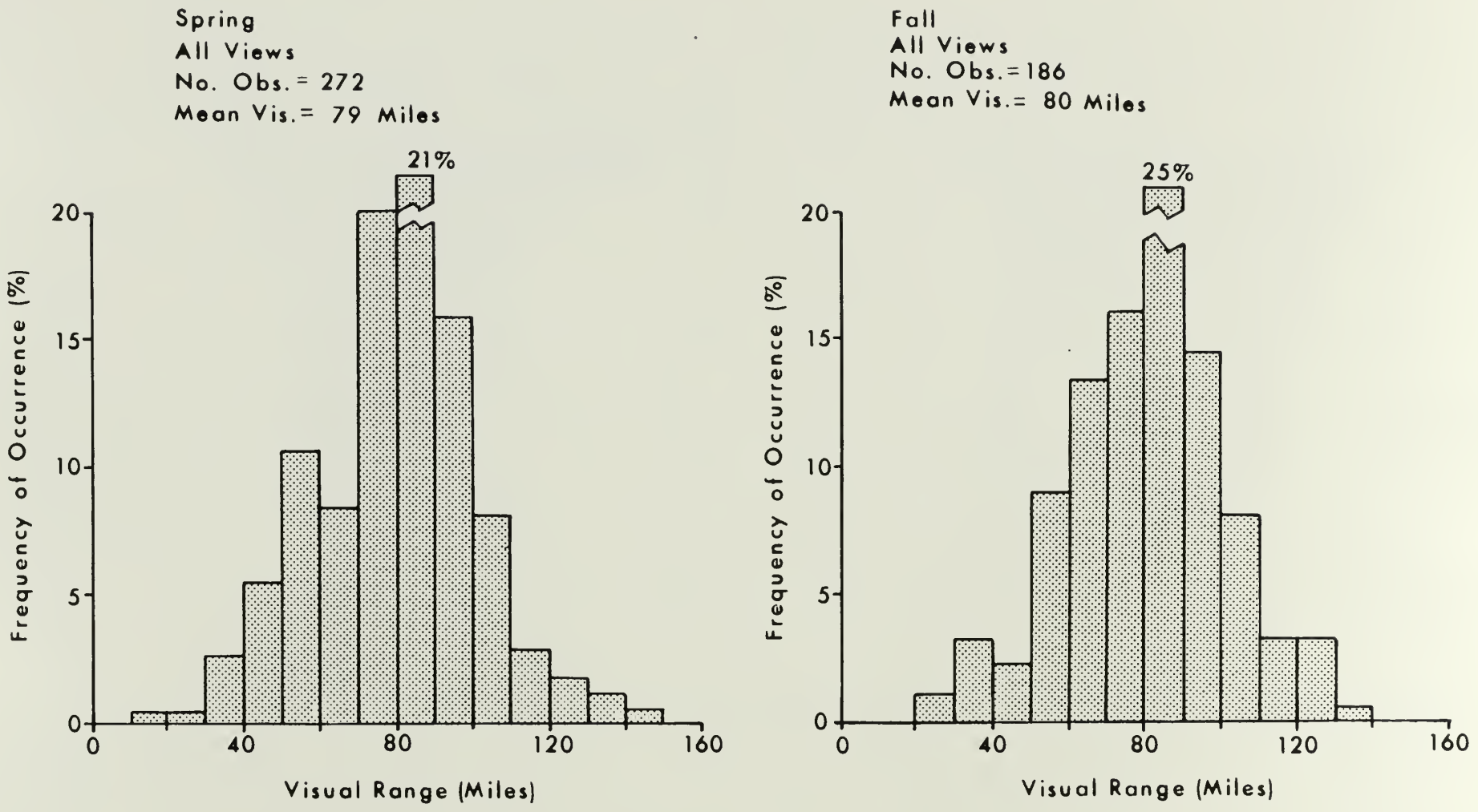

Figure 2-28. Seasonal Composite Distribution of Visual Range, Spring and Fall 1978, Piceance Creek Basin, Colorado

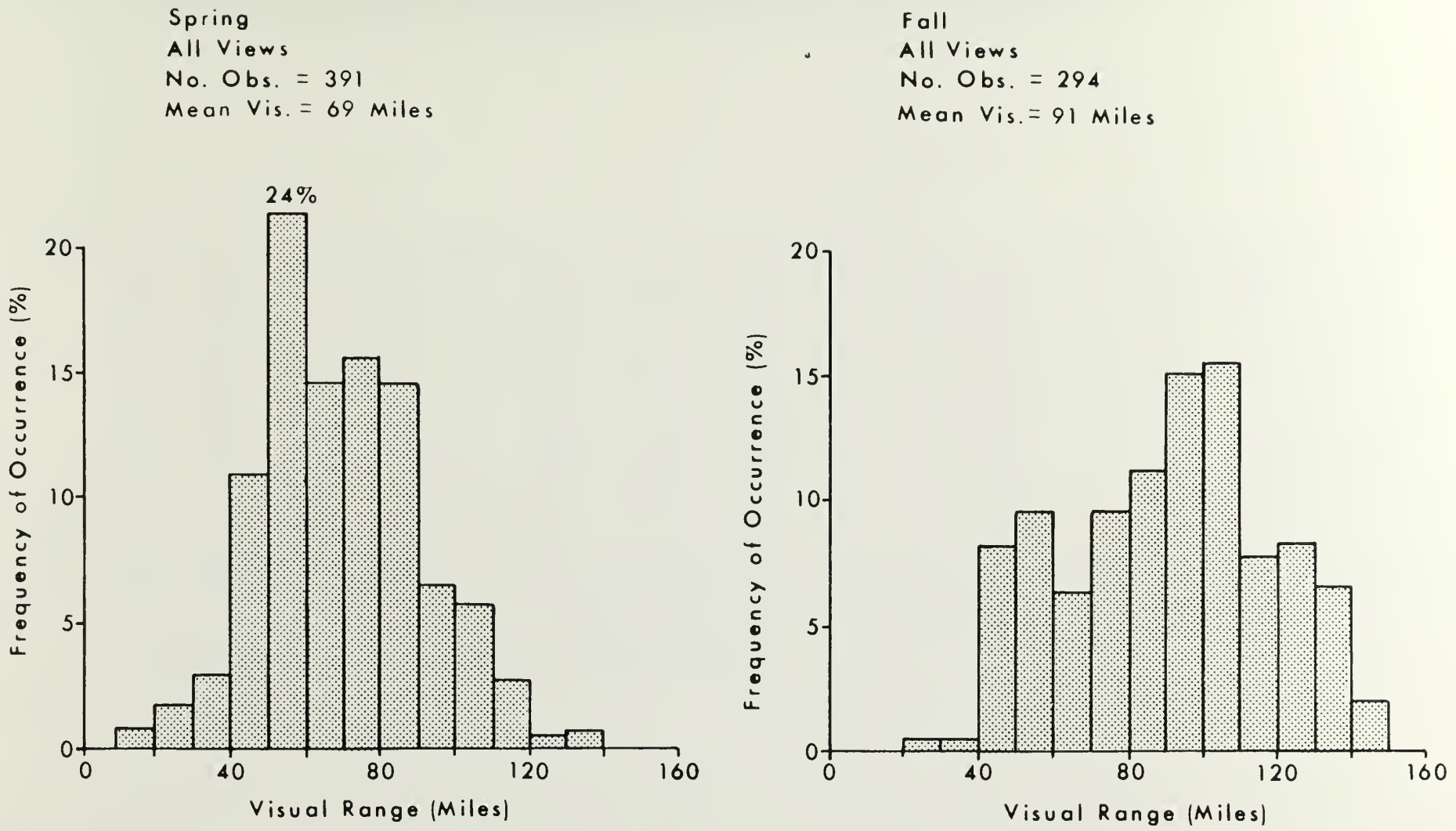

Figure 2-29. Seasonal Composite Distribution of Visual Range, Fall 1975 and Spring 1976, Piceance Creek Basin, Colorado

Table 2-35. Seasonal Visual Range Summary (Miles) for Four Periods: Fall 1975 and Spring 1976, Spring and Fall 1978, Spring and Fall 1979, and Spring and Fall 1980, in the Piceance Creek Basin, Colorado

		Mean				Hourly Maximum				Hourly Minimum				Standard Deviation			
	View	1975-76	1978	1979	1980	1975-76	1978	1979	1980	1975-76	1978	1979	1980	1975-76	1978	1979	1980
Spring	I	74	81	81	80	118	126	139	126	39	51	36	29	18.9	16.5	23.7	21.1
	II	63	73	73	72	113	112	129	102	32	32	43	35	16.5	17.1	19.4	14.0
	III	67	77	82	76	118	132	154	119	14	17	44	22	22.3	23.7	24.9	18.6
	IV	73	84	74	85	138	142	141	120	27	35	39	37	24.5	24.8	20.3	19.5
Fall	I	93	87	84	92	149	130	126	161	37	58	41	45	27.8	16.5	20.8	28.2
	II	77	76	76	83	142	102	132	156	42	55	41	47	23.6	11.7	16.6	21.8
	III	92	71	82	88	146	103	128	138	24	22	25	17	27.4	21.9	24.5	24.0
	IV	101	86	94	111	148	125	137	176	48	31	36	56	25.8	24.5	21.7	28.0

Table 2-36. Annual Visual Range Summary (Miles) for Four Periods: 1975-76, 1978, 1979, and 1980, in the Piceance Creek Basin, Colorado

View	Mean				Hourly Maximum				Hourly Minimum				Standard Deviation			
	1975-76	1978	1979	1980	1975-76	1978	1979	1980	1975-76	1978	1979	1980	1975-76	1978	1979	1980
I	83	83	83	85	149	130	139	161	31	51	36	29	23.0	16.7	22.1	25.1
II	69	74	74	77	142	112	132	156	31	32	41	35	19.2	15.2	18.1	18.7
III	78	74	82	82	149	132	154	138	14	17	25	17	26.6	23.0	24.6	22.0
IV	85	85	83	97	148	142	141	176	22	31	39	37	28.8	24.6	23.1	27.0
Composite	79	79	80	85	149	142	154	176	14	17	25	17	25.3	20.9	22.3	24.6

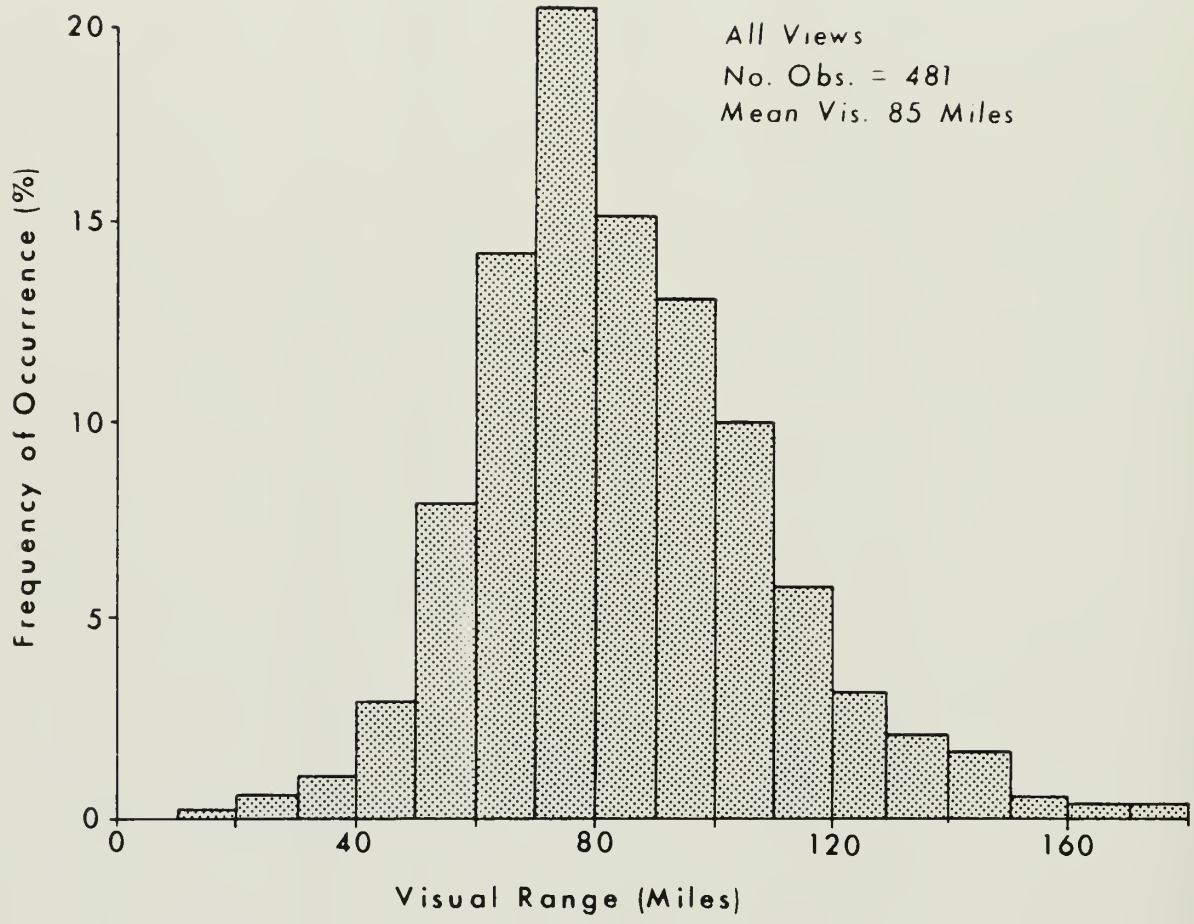

Figure 2-30. Annual Composite Distribution of Visual Range, 1980, Piceance Creek Basin, Colorado

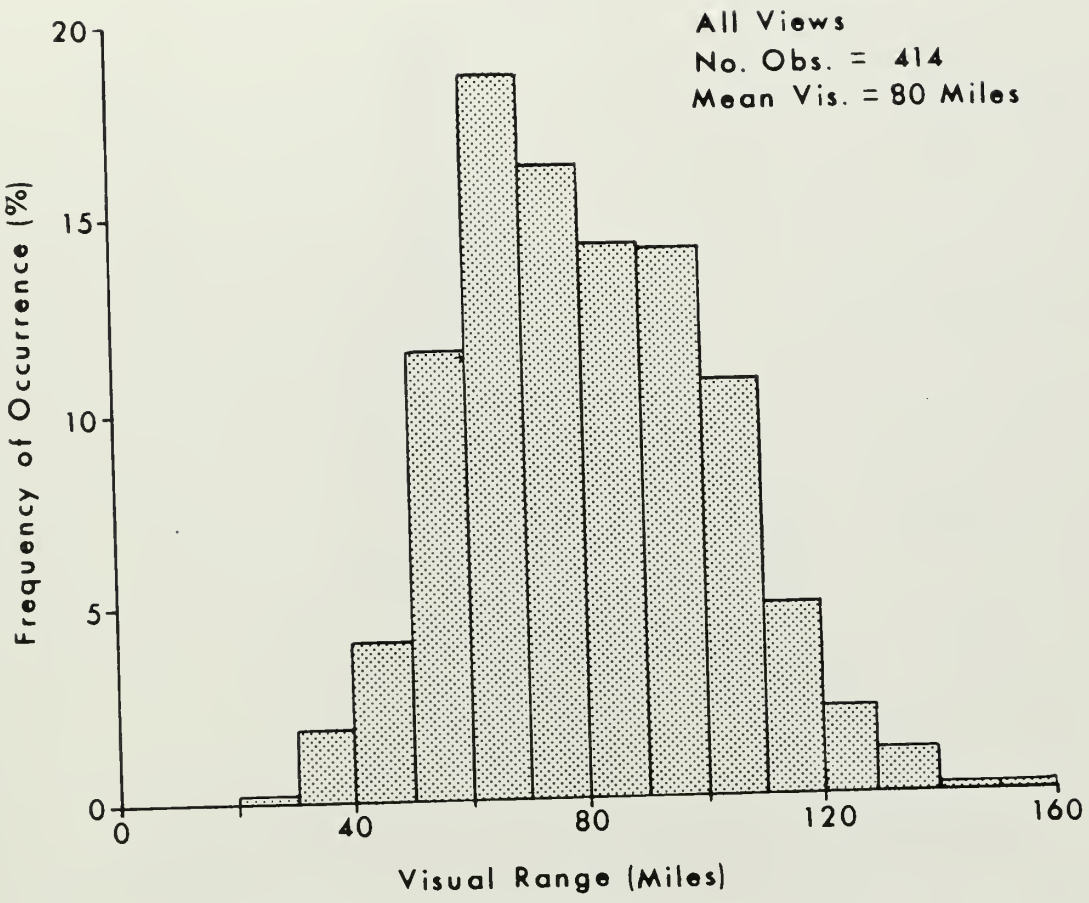

Figure 2-31. Annual Composite Distribution of Visual Range, 1979, Piceance Creek Basin, Colorado

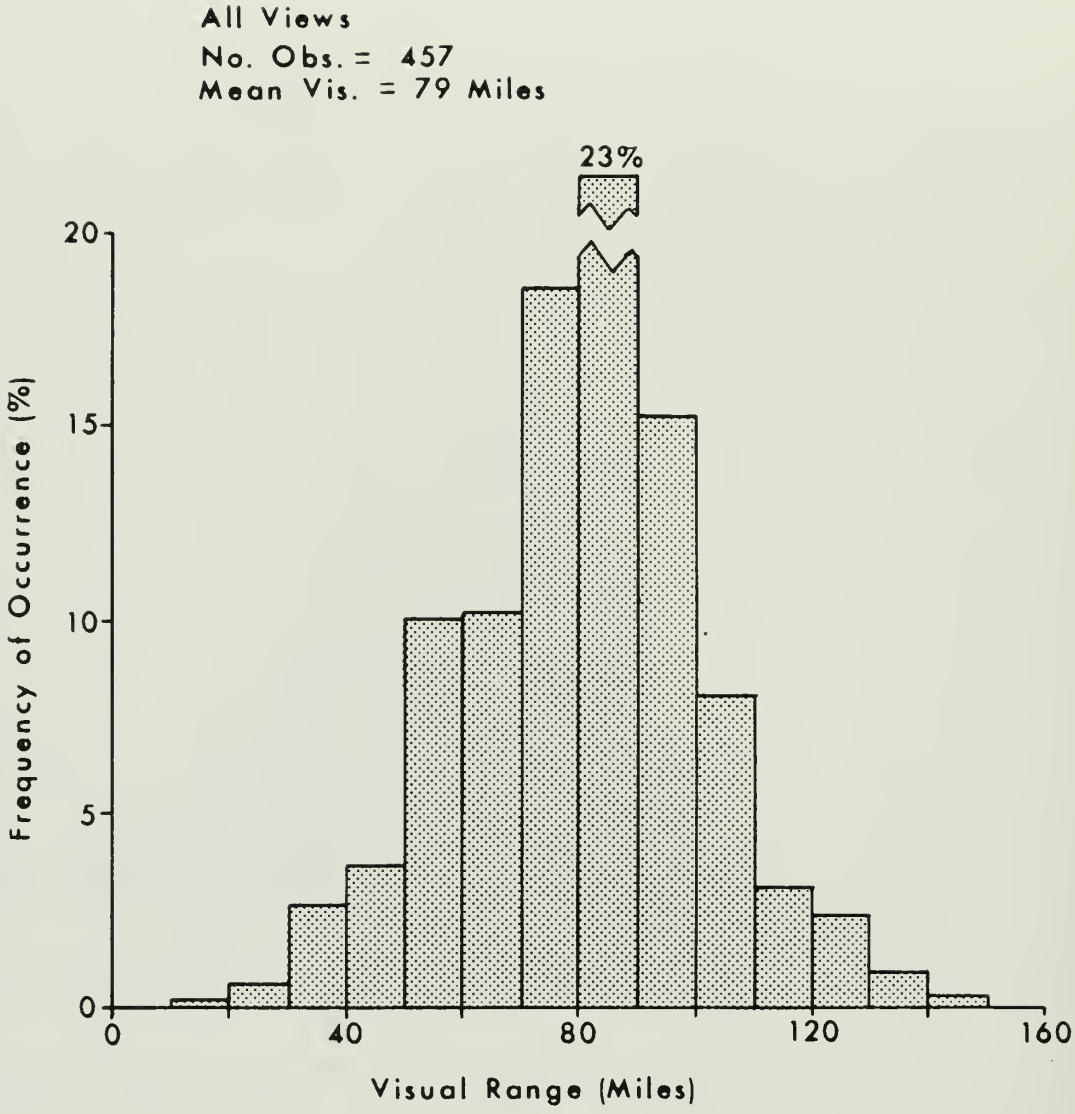

Figure 2-32. Annual Composite Distribution of Visual Range, 1978, Piceance Creek Basin, Colorado

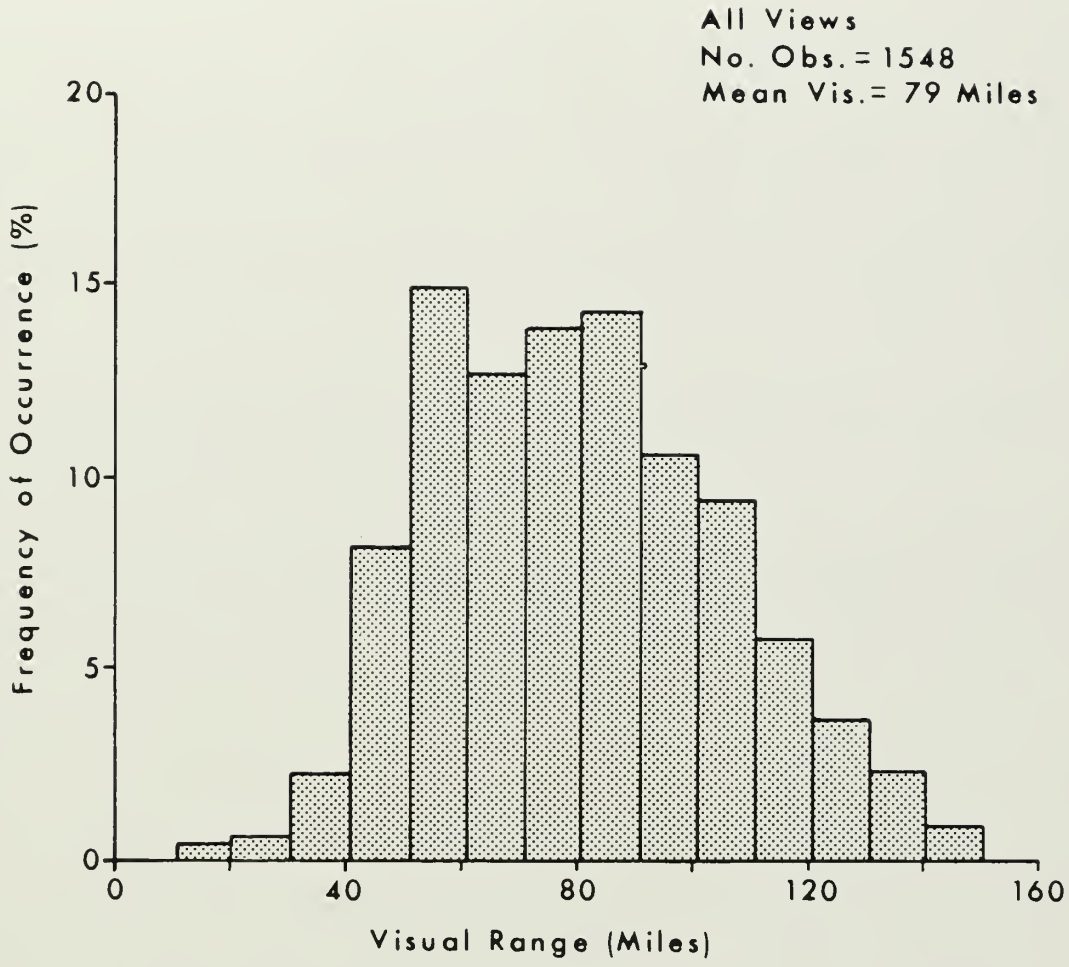

Figure 2-33. Annual Composite Distribution of Visual Range, 1975-76, Piceance Creek Basin, Colorado

Hourly maximum visual ranges obtained during the current year varied among the views; maximum values ranged from 138 miles in View III to 176 miles in View IV (both of which were measured in the fall). Hourly minimum visual ranges varied somewhat less than the maximum values, ranging from 17 miles in View III to 37 miles in View IV.

This summary of the visibility data has shown that there has been no apparent change in the mean visual range measured at the visibility monitoring site since the original study was conducted in 1975-76. A review of the data indicates there is at least as much variation in visual range among the views and between sampling days as there is between monitoring years.

2.6 NOISE

Development activities on Tract C-a will result in increased noise levels in the area. In order to assess the potential effects of these increased noise levels, it will be necessary to identify the sources of the noise and the intensity of noise levels at various distances from these sources. The RBOSC noise survey is designed to provide these data.

1. Objectives

Regulations regarding allowable noise levels have been promulgated for the safety and well being of humans. None of the existing regulations apply to effects of noise on wildlife, although some research has been conducted in this area (EPA 1971). The following are the objectives of the environmental noise program:

- Provide a data base on relative noise levels at various distances from sources on the tract
- Provide data for use by wildlife biologists in assessing the overall impacts of tract development on wildlife behavior and use of the study area.

2. Methods

In order to acquire the necessary noise level measurements, sound level readings are taken once each quarter at strategic monitoring sites around the mine development area. During the period of study, two noise surveys were made. Noise measurements were taken at 16 monitoring sites on September 5 with a General Radio Model 1565-B sound level meter, which had a minimum detectable threshold of 40 dBA. Measurements were also taken at the same monitoring sites on November 17 with a General Radio Model 1565-D sound level meter, which had a threshold of 30 dBA.

The monitoring sites were arranged in a configuration of concentric circles at various distances from the area of mine activity out to the borders of Tract

C-a, as described in Table 2-37. One other reading was taken in close proximity to the headframe for an indication of highest noise levels.

The methods followed in the collection of noise data were described in RBOSC MDP Monitoring Report 3 and are not repeated herein.

3. Results and Discussion

Sound level readings taken during the two surveys are shown in Tables 2-38 and 2-39. The highest average decibel levels were 69 dBA in the September survey and 74 dBA in the November survey. Both of these readings were obtained at the monitoring site near the headframe, which is the focal point of onsite activity. Most of the background noise levels in the September survey were below the instrument detection level (40 dBA), as were many of the levels in the November survey (a more sensitive meter had a lower threshold of 30 dBA). Background noise levels were reached when readings were taken at distances greater than about one mile from the MIS process site. Exceptions to background noise were noted when there were aircraft passing overhead, vehicular traffic, or some other activity, such as an oil drilling rig operating near the monitoring site.

Noise levels taken during these two surveys were generally comparable to those taken during the previous quarterly noise surveys. The potential for wildlife disturbances due to noise of this magnitude is anticipated to be small.

Table 2-37. Locations of Environmental Noise Monitoring Sites, Tract C-a

Site Number	Locations/Descriptions
1	Top of knoll N.E. of Hunting Camp, E. of road down to Corral Gulch
2	South side of site access road, 20 ft S.W. of "Hill" signs
3	N.E. corner of intersection of Airplane Ridge Road and tank access road
4	South side of Corral Gulch Road at fence corner slightly past power line
5	100 ft. S.E. from well CE-707, on line between survey point and headframe
6	Northwest of Well TO-2 outside of fence, 10 ft W. of survey point
7	North side of Corral Gulch Road at Well G-S 4-5 on top of road cut
8	West side of Wolf Ridge road on small knoll directly across from entrance to Well G-S 6 and trailer camp
9	North side of fenced area at Well TO-1 near entrance
10	South side of Box Elder Gulch Road at N.E. fence corners for Well AM-3
11	North side of Corral Gulch Road at turn-around area, across from U.S.G.S. stream gauging station
12	South side of road to Met. Site #1, 0.1 mile from power line crossing and S.W. corner of well G-S 1
13	North side of Wolf Ridge Road, N.E. corner of road to Well G-S 10
14	South side of Wolf Ridge Road at Tract C-a boundary line
15	East side of road, 0.15 mile north of Met. Site #2 access road
16	North of County Road 24 at intersection of Wolf Ridge Road
A	Approximately 30 ft east of main shaft headframe

Table 2-38. Environmental Sound Level Measurements Tract C-a, September 5, 1980

Site	Time	Wind	Sound Level Measurements (dBA, Slow Response) (20 sec range) 1	2	3	4	5	Sound Level Range (dBA)	Sound Level Average (dBA)[1/]	Remarks
A	0841	Calm	67-68	67-68	67-68	67-69	68-71	67-71	68	Job noise
1	0850	Calm	45-47	45-48	45-51	45-47	45-48	45-51	47	Job noise
2	1133	0-5 mph/NW	<40-45	<40-48	41-44	<40-56	<40-50	<40-56	-	Job noise, small truck
3	1124	Calm	48-53	47-55	46-53	45-51	45-50	45-55	49	Job noise
4	0930	Calm	<40	<40	<40	<40	<40	-	-	
5	0916	Calm	<40-42	<40	<40-43	<40-41	<40-41	<40-43	-	
6	0922	Calm	<40	<40	<40	<40	<40	-	-	
7	0951	3-5/SE	42-46	41-45	42-47	41-46	41-43	41-46	43	Job noise
8	1006	0-3/SE	<40	<40	<40	<40	<40	-	-	
9	1050	0-3/SE	<40	<40	<40	<40	<40-43	-	-	
10	1102	Calm	<40	<40	<40	<40	<40	-	-	
11	0937	Calm	<40	<40	<40	<40	<40	-	-	
12	0910	Calm	<40	<40	<40	<40	<40	-	-	
13	1015	0-3/SW	<40	<40	<40	<40	<40	-	-	
14	1025	0-5/S	<40	<40	<40	<40	<40-42	-	-	
15	1033	0-3/S	<40	<40	<40	<40	<40	-	-	
16	1000	0-3/NW	42-44	42-44	42-44	42-44	42-48	42-48	43	Heavy equipment
A	1140	0-3/NW	67-70	68-71	68-71	67-71	68-70	67-71	69	Job noise

[1/] Representative sound level averages cannot be computed in some instances because measurements were below the minimum threshold of the instrument

Table 2-39. Environmental Sound Level Measurements Tract C-a, November 17, 1980

Site	Time	Wind	Sound Level Measurements (dBA, Slow Response) (20 sec range) 1	2	3	4	5	Sound Level Range (dBA)	Sound Level Average (dBA)[1/]	Remarks
A	0916	Calm	69-72	70-72	69-72	71-77	69-95	69-95	74	Job noise - process area
1	1305	Calm	40-47	42-50	44-49	43-49	40-44	40-50	45	Job noise
2	1256	0-3 mph/E	<30-75	<30	<30-31	<30-33	<30-40	<30-75	-	Job noise, traffic
3	1246	Calm	39-44	39-43	38-42	38-41	40-42	38-44	41	Job noise
4	1012	0-2/E	33-39	34-41	33-42	30-37	32-39	30-42	36	Job noise
5	0953	0-2/E	36-39	36-39	35-38	33-38	34-39	33-39	37	Job noise
6	1002	0-2/E	32-37	35-38	35-39	34-38	33-37	32-39	36	Oil drilling rig
7	1033	0-2/S	30-37	30-40	32-68	32-46	35-49	30-68	40	Job noise, truck
8	1043	Calm	<30	<30	<30	<30	<30	-	-	
9	1215	2-4/E	<30	<30	<30	<30	<30	-	-	
10	1228	0-3/E	<30	<30	<30	<30	<30	-	-	
11	1022	0-2/S	<30	<30-36	<30	<30	<30	<30-36	-	
12	0942	0-2/E	39-42	39-45	39-43	38-42	36-40	36-45	40	Jet, distant trucks, oil drilling rig
13	1051	Calm	<30-31	<30-32	<30-31	<30-39	<30-39	<30-39	-	Heavy equipment audible
14	1059	Calm	<30-40	<30-44	<30-35	<30	<30	<30-44	-	Jet noise
15	1107	0-2/N	<30	<30	<30	<30	<30	-	-	
16	1237	0-2/NE	31-37	31-33	<30-32	<30-32	<30-32	<30-37	-	
A	1312	Calm	71-76	71-77	70-72	70-80	70-72	70-80	73	Job noise - process area

[1/] Representative sound level averages cannot be computed in some instances because measurements were below the minimum threshold of the instrument

2.7 SUMMARY

Both air quality and meteorological data were collected during the reporting period. The major event related to air quality occurring within this period was the burning of Retort 0. The maximum concentration of SO_2 (the major air pollutant of concern released from the retort) measured during the burn was 0.022 ppm at Site 1. Since this SO_2 concentration was measured during easterly wind conditions (which would transport the stack emissions in the direction of Site 1), it is quite likely that this measurement resulted from the Retort 0 burn. It should be noted, however, that this concentration is near the threshold of detection of the instrument, being only about four percent of full scale.

The ozone concentrations found on the tract varied from 0.003 to 0.070 ppm, well below the National Ambient Air Quality Standard (NAAQS) for ozone of 0.12 ppm. The diurnal cycle in ozone concentrations was greater at Site 3 than at Site 1. The larger cycle at Site 3 results from nighttime inversions which develop within the gulch in which Site 3 is located. The inversions effectively seal off the gulch from exchange with the rest of the atmospheric boundary layer, allowing ozone destruction reactions to reduce the ambient ozone concentrations at night.

The source of the relatively high ozone concentrations measured at the tract has not been definitely identified, although these concentrations have been found to be typical of many other remote locations. There has been no evidence of local photochemical production from either natural or anthropogenic sources.

Total suspended particulates (TSP) did not exceed the NAAQS during the current year. Multiple and stepwise regression analyses were carried out on the particulate data, using a combination of meteorological and site activity variables. The highest correlations were found using the annual rather than the seasonal TSP data sets. Approximately two-thirds of the annual variability of TSP concentrations could be explained by the meteorological and site activity variables. This is very similar to the results of regression analyses performed for the two previous years.

Site activity parameters ranked no higher than third in explaining the variability of TSP concentrations, and contributed only minor improvements to the regression analysis. Temperature was by far the most successful predictor, largely because it has an annual cycle similar to the TSP data, and it serves as an indicator variable for other important parameters, such as soil moisture.

Review of the 1980 meteorological data revealed that 1980 meteorology was similar to previous years. Precipitation at the tract averaged approximately 12 inches during the current year. The temperature range of 48 C (-16 C to +28 C) measured during the current year at Site 1 is typical of continental sites. Wind speed at the tract has been relatively low, reaching a maximum of 32 mph at the 10-m level at Site 1. Winds have been predominantly out of the west and southwest.

The 1980 visibility monitoring program indicated a slight increase in visual ranges in the Piceance Creek Basin. The mean annual visual range during 1980 was 85 miles, which compares with visual ranges of 79 or 80 miles measured during the three earlier years of monitoring. There is a large day-to-day variability in the visual range, but this is primarily a result of widely varying meteorological conditions. The maximum visual range measured in 1980, 176 miles, was the highest value in the four years of monitoring. Visual ranges near 150 miles were also recorded during each of the three previous years. These values approach the theoretical limit of visual range in the atmosphere (200 miles).

Two noise surveys were taken during the reporting period. The measured sound levels generally ranged from less than 30 dBA (the threshold of the instrument) to 50 dBA, except near the main construction area (adjacent to the headframe), which averaged 71 dBA. If the measurements taken near the main construction area are excluded, these sound levels are comparable to data taken during the baseline period.

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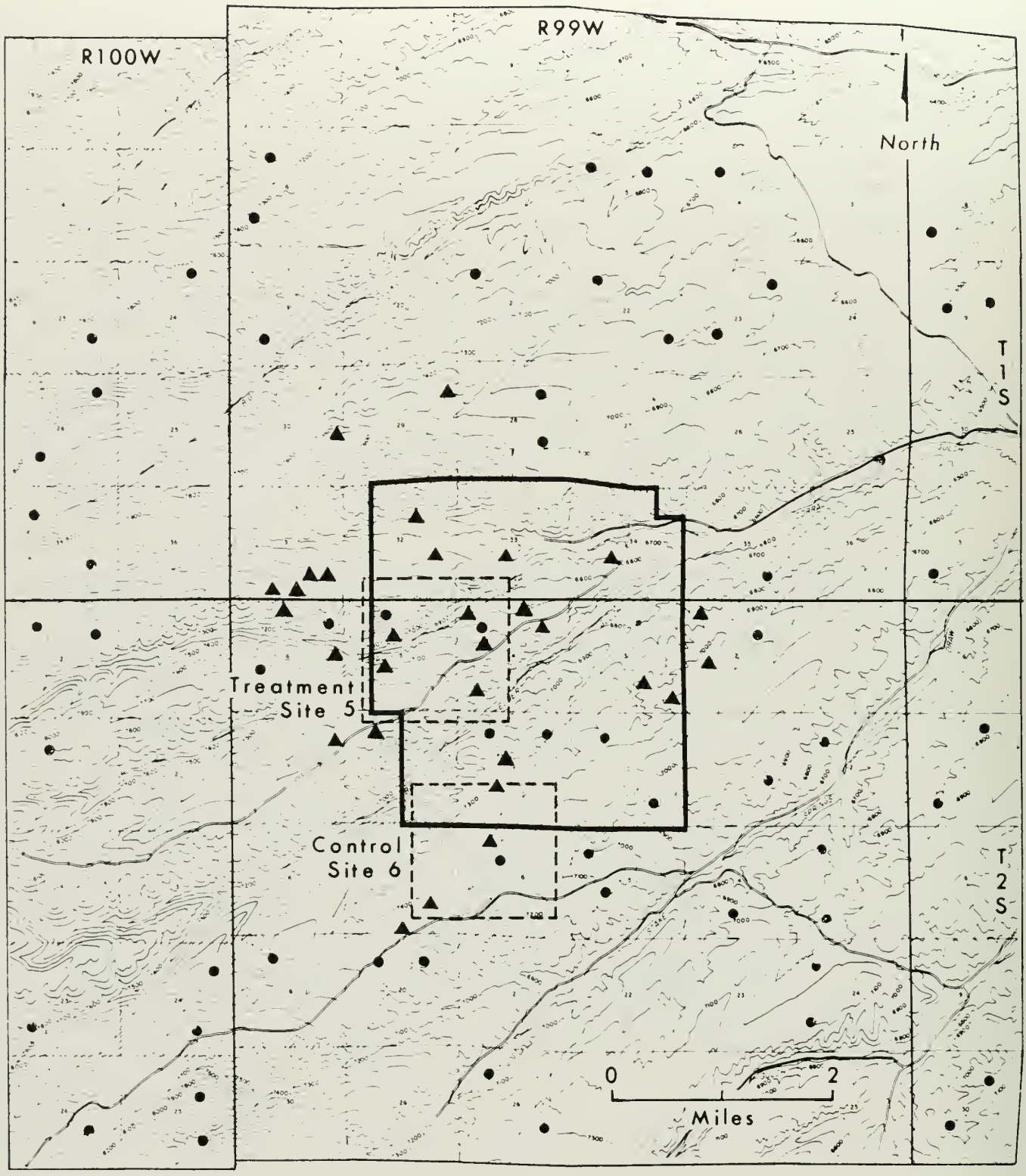
SECTION 3
TERRESTRIAL STUDIES

The Terrestrial Studies MDP Monitoring Program is designed to detect and evaluate those impacts affecting the vegetation or faunal components of the terrestrial ecosystems on or near Tract C-a.

The Tract C-a terrestrial studies are geared to seasonal cycles of the ecosystem components, therefore, sampling is conducted during those seasons when the appropriate measurements can be made. The study period reported herein is December 1979 through November 1980. Vegetation stress based on color infrared (CIR) photography, phytosociology, range productivity and utilization, browse condition and utilization, small mammal, avifauna, mule deer, and feral horse studies are reported herein. Figure 3-1 illustrates the locations of terrestrial monitoring sites. Opportunistic observations of important events and unscheduled special studies are included in MDP monitoring reports as they occur.

The terrestrial monitoring program is based on an assessment of current knowledge of MDP mining and processing operations. Because this is a prototype operation, new information may become available which requires a modification of the outlined program. Therefore, this monitoring program should be viewed as a flexible one which may change as engineering design is refined and as additional ecological data are obtained.

Terrestrial data presented in this report were collected according to the methods described in the Modular Development Phase Environmental Monitoring Program Scope of Work, Revision 5.2 (RBOSC 1979c). All data were verified in compliance with RBOSC quality control procedures, including supervisory verification of field data sheets, laboratory analysis and data management processes. Documentation supporting these quality control procedures appear in the RBOSC Quality Assurance files.



● Mule Deer Pellet Group Sample Unit
▲ Range Browse, Productivity & Utilization Study Site
[ ] Intensive Study Sites

Figure 3-1. Terrestrial Ecology Monitoring Sites.

3.1 VEGETATION, RANGE AND BROWSE

A. Vegetation Mapping and Stress

1. Objectives

Construction and operation of Tract C-a facilities may affect the local distribution and/or condition of vegetation types. The vegetation studies are designed to monitor the distribution of vegetation on Tract C-a and adjacent areas to determine large-scale changes resulting from MDP development, to identify stress conditions, and to document changes over time in the plant communities. Documentation of plant community distribution and condition is accomplished via color and CIR aerial photography.

2. Methods

Color and CIR aerial photographic studies follow methods detailed in MDP Reports 1 and 4 (RBOSC 1978a, 1979b). The areas photographed using CIR during June 1980 included the following major drainages on and adjacent to Tract C-a:

- Stake Springs Draw from Range 100 W downstream to Yellow Creek
- Box Elder Gulch from Range 100 W downstream to the confluence with Corral Gulch
- Water Fork of Corral Gulch from Range 100 W downstream to the confluence with Yellow Creek
- Big Duck Creek from Range 100 W downstream to the confluence with Yellow Creek
- Yellow Creek downstream to the White River

Color balance on the 1980 CIR photographs was matched to that of 1979 photographs so that direct comparisons would be more meaningful.

3. Results and Discussion

Detailed study of the 1980 CIR photographs and/or transparencies showed several minor differences in the distribution of areas on Tract C-a which support vegetation indicative of moderate soil moisture. When soil moisture is moderate to relatively abundant, mesic, herbaceous plant species are favored. This type of vegetation can be identified on CIR photographs by the presence of red tones. Such areas identified from 1974 and 1979 photography along with the minor changes noted from 1980 photographs are illustrated on Figure 3-2. It is assumed that the minor variations noted between 1979 and 1980 represent qualitative differences based on variations in color balance of photographs and on the researcher's visual inspection of the photographs. Apparent decreases in moisture were noted in Box Elder Gulch and to the north of Dry Fork of Corral Gulch. Apparent increases in moisture were noted on Sagebrush Ridge and to the northeast of the Mine Site Area. At several locations around the Mine Site Area where revegetation has taken place on soil storage piles the relatively lush vegetation was evident, with increases in red tones being noted from 1979 to 1980. These sites are labeled 'MDP' on Figure 3-2. Data seem to indicate that dewatering and reinjection and/or discharge of water on Tract C-a during the reporting period have not altered, to any large degree, the vegetational communities present during the 1979 sampling period.

Results of the analysis of photographs covering areas beyond the boundaries illustrated on Figure 3-2 are not reported herein but will serve as baseline information should the influence of Tract C-a activities extend to these areas.

B. Phytosociological Studies

1. Objectives

The objective of the phytosociological studies is to monitor species composition and coverage in the major vegetation types expected to be affected by Tract C-a development. These studies provide quantitative data which complement information on distribution of major habitat types and provide continuity with similar data collected during the baseline period.

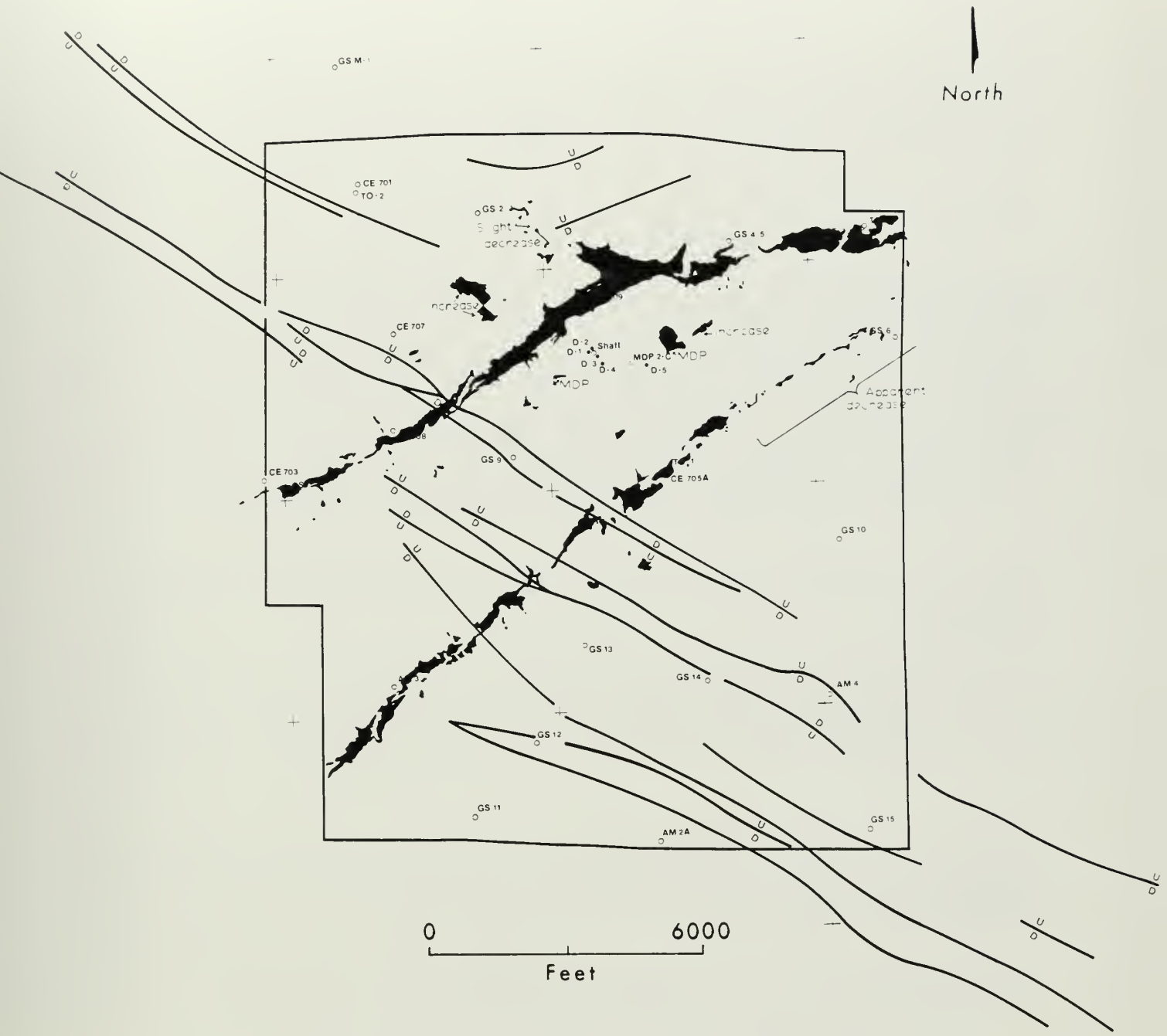


Figure 3-2 . Variations in Moisture Regime Based on Color Infrared Photography of Tract C-a (Prepared by R.A. Hodgson)

2. Methods

Phytosociological studies are conducted in pinyon-juniper and sagebrush vegetation types in a control site south of Tract C-a (Location 6) and in a treatment site on Airplane Ridge (Location 5) (Figure 3-1). These sites correspond to the sampling locations for the small mammal and avifauna studies. The "treatment" defined as part of the monitoring program includes potential effects of air pollutant emissions and other associated impacts. Potential impacts will be assessed after the retorts are burned. As development progresses the treatment site will be moved as necessary.

Phytosociological sampling is conducted in May-June once every three years in a specific vegetation type on a rotation basis. During the initial sampling period in each type, density and cover of woody species and cover of herbaceous species are determined; thereafter only herbaceous cover will be measured. Sampling began in June 1979 in the pinyon-juniper type and was conducted in the upland sagebrush vegetation type during 1980. Methods followed for collection of these data were presented in MDP Monitoring Report 5 (RBOSC 1980a).

Analyses for phytosociological studies are designed to test the following hypothesis:

> H_o: There is no significant difference in herbaceous cover within a vegetation type between years (before and during modular development).

With only one sampling year, herbaceous cover data were arcsine transformed and analyzed by the following nested Analysis of Variance (ANOVA) to compare treatment and control sites:

Source of Variation		Degrees of Freedom	F-Test
A.	Location a=2	a-1	A/D
B.	Transect b=5	b-1	B/D
C.	Location (Transect)	$a(b_i-1)$	C/D
D.	Error (n=100)	$ab(ab_i)(n-1)$	
	Total	$nabb_i-1$	

This nested ANOVA design was used to determine the differences in herbaceous cover between two locations (main effect A) and among transects within location (nested effect B). The nested effect (C) tests the transect within location interaction. If the nested effect is significant, then multiple range tests were performed to determine the source of the interaction. A one-way ANOVA for transects within each location also was performed. This test served to confirm results of the nested ANOVA, in which differences among transects within location may have been masked by considering the combined influence of both control and treatment areas.

Because the woody species data are collected only once, these data are not amenable to ANOVA. For the first year's data, however, tree and shrub coverage within the control and treatment areas also was compared using the aforementioned ANOVA. In subsequent years these data will serve as additional "baseline" information for the control and treatment sampling sites and will be used in the interactions analyses along with the wildlife data. If impacts are detected by photoplot or vegetation distribution monitoring programs, then additional sampling programs for woody species will be initiated.

3. Results and Discussion

Transects were sampled in the upland sagebrush vegetation type between June 5-17, 1980. Photoplots for all transects were established during the same period. Ranges and averages for coverage and/or density of species encountered along the five transects within each location are reported herein and raw data are presented in Appendix 3-1.1.

Average coverage of trees and shrubs was 23.6 percent in the control area (6) and 31.6 percent in the treatment area (5) (Table 3-1). Sagebrush (Artemisia tridentata) was the dominant woody species in both locations, accounting for 86 and 64 percent of all shrub and tree coverage in the control and treatment areas respectively. Serviceberry (Amelanchier utahensis), rabbitbrush (Chrysothamnus nauseosus), and snowberry (Symphoricorpos oreophilus) were subordinant shrubs present in both locations, but contributed greater coverage in the treatment area than in the control location. Coverage of pinyon pine (Pinus edulis) and juniper (Juniperus osteosperma) was low in both locations,

Table 3-1. Coverage and Density of Tree and Shrub Species Encountered on Transects in the Upland Sagebrush Vegetation Type for Control Area 6 and Treatment Area 5 During 1980, Tract C-a

Species	Control Area (6)				Treatment Area (5)			
	Average Density (stems/ha)	Range (stems/ha)	Average Cover (%)	Range (%)	Average Density (stems/ha)	Range (stems/ha)	Average Cover (%)	Range (%)
Shrubs								
Amelanchier utahensis	420	267 - 583	1.1	0 - 3.5	947	567 - 1133	3.0	0.1 - 5.1
Artemisia tridentata	6060	5367 - 6817	20.3	16.9 - 26.9	7190	6217 - 9483	20.2	11.3 - 30.2
Chrysothamnus depressus	40	0 - 200	0.1	0 - 0.3	ND	ND	ND	ND
Chrysothamnus nauseosus	2437	1117 - 4017	1.6	0.7 - 3.8	5187	2700 - 6750	4.4	1.1 - 10.7
Purshia tridentata	ND	ND	ND	ND	17	0 - 67	ND	ND
Symphoricarpos oreophilus	170	0 - 617	0.3	0 - 1.4	1060	617 - 1550	3.6	1.2 - 7.0
Tetradymia canescens	560	0 - 1883	0.1	0 - 0.5	427	167 - 683	0.2	0 - 0.7
		Total Shrub Coverage	23.5				31.4	
Trees								
Juniperus osteosperma	13	0 - 50ND		ND 97	50	133 0.2	0	- 0.7
Pinus edulis	27	0 - 100	0.1	0 - 0.6	13	0 - 50	0.02	0 - 0.1
		Total Tree Coverage	0.1				0.2	
		Total Coverage of Woody Species	23.6				31.6	

0.1 percent and 0.22 percent, respectively (Table 3-1). A comparison of shrub and tree coverage between the control and treatment areas indicated that there were no significant differences between the two locations for either nested or main effects (Table 3-2a). A one-way ANOVA comparing coverage of woody species among transects within each location confirms that variations exhibited within the control and treatment areas are not significant (Table 3-2b).

Density of sagebrush averaged 6060 stems per hectare in the control area and 7190 stems per hectare in the treatment area. Other woody species exhibited greater variability in density between the two locations (Table 3-1). Rabbitbrush, the second most prominent shrub species encountered, exhibited densities of 2437 and 5187 stems per hectare in control and treatment areas respectively. Serviceberry and snowberry also had average densities which were considerably greater in the treatment than in the control area. These variations in density of subordinate shrub species are not evident to any large degree for coverage values, which are not significantly different between the areas (Table 3-2).

Grass species averaged 24.4 percent coverage in the control area and 19.2 percent in the treatment location (Table 3-3). Species composition for the two areas was similar, with Poa species being the most prominent grass in both locations. Wheatgrass (Agropyron spp.) species were the second most prominent species in the control area whereas Sitanion hystrix was the second most prominent species in the treatment area. Statistical comparisons of grass coverage between the two locations showed no significant differences in either nested or main effects (Table 3-2a). These findings were confirmed via a one-way ANOVA comparing transects within each location (Table 3-2b).

Mean coverage of forbs between control and treatment areas was more variable than that for grasses. Forbs in the control area exhibited 20.4 percent coverage as compared to 13.2 percent in the treatment area (Table 3-3). There also were slight differences in species richness and dominance between the areas. The number of species encountered in the control area exceeded that in the treatment site (38 vs. 31 species, respectively). The prominent species in the control area were Hedysarum and Lupinus, with respective coverages of 3.1 and 4.0 percent. Both of these species also were encountered in the treatment

Table 3-2. ANOVA Results Comparing Grass, Forb, Shrub and Tree Coverage on Transects in the Upland Sagebrush Vegetation Type for Control Area 6 and Treatment Area 5 During 1980, Tract C-a[1/]

a. Nested ANOVA

	Source of Variation					
	Location		Transect		Location (Transect)	
Growth Form	F	PR>F[2/]	F	PR>F[2/]	F	PR>F[2/]
Grasses	2.51	0.1198	0.27	0.8938	0.07	0.9910
Forbs	3.14	0.0779	0.31	0.8684	0.74	0.5642
Shrubs	0.10	0.7483	0.07	0.9918	0.13	0.9688
Trees	1.34	0.4531	2.25	0.4264	ND	ND

b. One-way ANOVA

		Source of Variation	
		Location	
	Growth Form	F	PR>F[2/]
Control Area 6	Grasses	0.16	0.9583
	Forbs	0.57	0.6872
	Shrubs	0.07	0.9898
	Trees	ND	ND
Treatment Area 5	Grasses	0.21	0.9329
	Forbs	0.46	0.7646
	Shrubs	0.13	0.9687
	Trees	2.25	0.4264

[1/] Complete analyses are presented in Appendix 3-1.2

[2/] PR>F represents the significance probability (α) assciated with F

Table 3-3. Coverage of Grass and Forb Species Encountered on Transects in the Upland Sagebrush Vegetation Type for Control Area 6 and Treatment Area 5 During 1980, Tract C-a

Species	Control Area (6) Average Cover (%)	Control Area (6) Range (%)	Treatment Area (5) Average Cover (%)	Treatment Area (5) Range (%)
Grasses				
Agropyron species	4.0	0.3 - 3.4	1.6	0 - 3.4
Bromus tectorum	2.4	0.2 - 6.4	0.4	0 - 2.0
Koeleria gracilis	2.4	0.6 - 4.4	0.2	0 - 0.6
Oryzopsis hymenoides	1.5	0 - 3.8	1.8	0.4 - 2.6
Poa species	11.8	7.3 - 16.5	6.6	5.6 - 7.4
Sitanion hystrix	ND	ND	5.5	0 - 0.1
Stipa comata	2.3	0.8 - 3.6	0.7	0 - 2.0
Unknown grass	ND	ND	2.4	0 - 6.0
	24.4		19.2	
Forbs				
Agoseris glauca	0.8	0.6 - 1.3	0.1	0 - 0.4
Arabis species	0.03	0 - 0.1	0.04	0 - 0.2
Aster species	ND	ND	0.1	0 - 0.5
Astragalus diversifolius	0.2	0 - 0.7	0.1	0 - 0.2
Astragalus purshii	0.4	0.2 - 0.7	0.2	0.05- 0.2
Balsamorhiza sagittata	0.7	0 - 2.2	ND	ND
Boraginaceae species	0.1	0 - 0.3	ND	ND
Castilleja species	0.1	0 - 0.2	0.1	0 - 0.2
Chaenactis douglasii	0.01	0 - 0.05	ND	ND
Chenopodium species	0.01	0 - 0.05	ND	ND
Comandra umbellata	0.3	0.2 - 0.4	0.04	0 - 0.2
Crepis occidentalis	1.6	0.3 - 2.5	0.4	0.2 - 0.8
Cryptantha sericea	1.0	0.1 - 2.1	0.6	0.05- 2.4
Delphinium nelsonii	0.04	0 - 0.2	0.1	0 - 0.1
Descurainia richardsonii	0.01	0 - 0.05	0.02	0 - 0.1
Erigeron eatonii	0.5	0.2 - 1.0	1.0	0.2 - 1.6
Eriogonum umbellatum	0.2	0 - 0.8	ND	ND
Erysimum asperum	0.02	0 - 0.1	ND	ND
Haplopappus nutallii	0.3	0 - 1.2	ND	ND
Hedysarum boreale	3.1	1.0 - 5.2	1.9	0 - 5.8
Ipomopsis aggregata	0.04	0 - 0.2	ND	ND
Linum lewisii	0.1	0 - 0.3	ND	ND
Lithospermum species	0.1	0 - 0.6	0.1	0 - 0.2
Lomatium species	0.3	0 - 0.8	0.1	0 - 0.2
Lupinus argenteus	4.0	0 - 11.0	0.7	0 - 2.2
Opuntia species	0.1	0 - 0.7	0.04	0 - 0.2
Penstemon caespitosus	ND	ND	0.4	0 - 0.9
Penstemon species	0.1	0 - 0.2	0.1	0 - 0.3
Phlox hoodii	1.2	0 - 3.0	3.8	2.4 - 4.8
Phlox longifolia	1.3	0.6 - 1.6	1.0	0.6 - 1.6
Physaria floribunda	0.1	0 - 0.2	0.1	0 - 0.2
Senecio integerrimus	1.1	0 - 5.2	0.1	0 - 0.4

Table 3-3. (Continued)

Species	Control Area (6) Average Cover (%)	Control Area (6) Range (%)	Treatment Area (5) Average Cover (%)	Treatment Area (5) Range (%)
Senecio multilobatus	0.2	0 - 0.7	0.1	0 - 0.3
Sisymbrium linifolium	0.1	0 - 0.2	0.2	0.05- 0.4
Sphaeralcea coccinea	0.7	0.2 - 1.7	0.7	0.2 - 1.4
Taraxacum officinale	ND	ND	0.1	0 - 0.1
Townsendia incana	0.3	0 - 1.0	0.1	0 - 0.2
Trifolium gymnocarpon	0.7	0.4 - 1.2	0.7	0.2 - 1.0
Unknown composite	0.2	0 - 1.0	0.1	0 - 0.2
Unknown species	0.2	0 - 0.4	ND	ND
Zigadenus venenosus	0.1	0 - 0.2	0.01	0 - 0.05
Total Forb Coverage	20.4		13.2	
Total Herbaceous Coverage	44.8		32.4	

site but exhibited noticeably lower coverage values. The most prominent species in the treatment site was Phlox hoodii, with an average coverage of 3.8 percent.

Statistical comparisons between control and treatment areas showed no significant difference in forb coverage (Table 3-2). The lack of a significant difference when mean coverage in the control area is 1.5 times that of the treatment area can be attributed to the high degree of variability exhibited among transects. This variability is evidenced in the ranges presented on Table 3-3. It should be noted that relatively few species occur on all five transects within either of the areas.

Lower grass and forb coverage noted on the treatment as compared to the control area may be related to shrub coverage and/or density. The higher shrub coverage in the treatment area (compared to the control area) would result in greater competition for constituents that may be limiting factors such as moisture and consequently afford a less favorable environment for grass and/or forb growth.

C. Range Productivity and Utilization

1. Objectives

Tract C-a MDP activities may affect range conditions on and near the tract by altering use patterns of deer, cattle, and feral horse populations, thus changing grazing pressure. The range studies are designed to provide information which can be used to compare range productivity and utilization before and during modular development. Because activities associated with tract development are confined primarily to the mine process area, impacts on range conditions are projected to be localized. Therefore, range studies focus on areas of Tract C-a and vicinity that are adjacent to MDP activities, and that previously were used for grazing.

2. Methods

The methods followed for collection of range data were described in MDP Monitoring Reports 1, 2, 3, 4 and 5 (RBOSC 1978a, 1978b, 1979a, 1979b, 1980a). During the current reporting period, Pachistima myrsinites and Mahonia repens two shrub species heretofore included in range sampling, were dropped from the analyses. Although these species are included within the grass/forb stratum, they are shrub species that are not typically utilized as forage.

The range productivity data are analyzed by using the following two-way ANOVA to compare pre-development conditions with those during development.

	Source of Variation	Degrees of Freedom	F-Test
A.	Year a = 3	a-1	A/D
B.	Protected vs. Unprotected Plots b = 2	b-1	B/D
C.	Phase x Plots	(a-1)(b-1)	C/D
D.	Error	ab(n-1)	
	Total	abn-1	

In order to test for differences which may have been masked by lumping plot types in the aforementioned ANOVA, production data for each vegetation type also were analyzed using one-way ANOVA in order to ascertain differences among transects for 1980, as well as among vegetation types for 1978, 1979, and 1980.

3. Results and Discussion

The 30 range transects (Figure 3-1) were sampled September 3-17, 1980. With the exception of transect 18, locations of the sampling sites were identical to those reported in the MDP Scope of Work (RBOSC 1979c). Transect 18 was disturbed by Tract C-a development activities and was replaced by transect 40, located adjacent to transect 18.

Range productivity data from the 1980 sampling period are summarized in Table 3-4 and the complete data set is included in Appendix 3-1.3.

Table 3-4. Range Production (standing crop, dry weight, kg/ha) of Species Encountered in Caged and Uncaged Plots Within Three Vegetation Types During 1980, Tract C-a

Species	Mixed Brush		Pinyon-Juniper		Upland Sagebrush	
	Caged	Uncaged	Caged	Uncaged	Caged	Uncaged
Plots (N)[1/]	(49)	(50)	(50)	(50)	(49)	(50)
Grasses						
Agropyron spp.	82.3	48.2	8.6	9.6	75.2	35.2
Bromus tectorum	0.3	0.4	0.5	0.2	30.1	8.1
Carex spp.	1.2	4.1	3.4	1.6	3.3	1.2
Koeleria gracilis	2.9	2.2			0.9	1.5
Oryzopsis hymenoides	39.6	22.6	9.1	4.1	14.2	4.6
Poa spp.	29.7	33.1	16.8	18.1	23.0	25.1
Sitanion hystrix	2.5	0.6	5.0	2.1	9.7	17.4
Stipa spp.	0.6	0.3		0.4	0.5	0.8
Total Grasses (kg/ha)	159.1	111.5	43.4	36.1	156.9	93.9
Forbs						
Achillea lanulosa	0.3	0.4				
Agoseris sp.					0.3	0.2
Antennaria sp.	1.1	1.5		0.1	0.6	2.1
Arenaria fendleri	0.3		0.6	0.1		
Artemisia ludoviciana		1.1				
Aster sp.	1.2	1.3	0.1		0.1	
Astragalus convallatius		0.3				0.1
Astragalus diversifolius	4.2	0.9			1.8	5.3
Astragalus spp.	0.3	0.4	0.5	0.6	11.6	0.1
Balsamorhiza sagittata		2.0	10.1	6.3	2.2	1.4
Boraginaceae spp.			0.5	0.3		
Chaenactis douglasii	0.2	1.3			0.2	0.1
Chenopodium album			0.1			
Chenopodium spp.			0.1			
Comandra umbellata	17.9	27.0	0.5		6.5	1.8
Crepis spp.	4.2	2.5			2.2	0.9
Cruciferae spp.	2.6	0.4	0.7	0.2	1.3	0.8

Table 3-4. (Continued)

Species	Mixed Brush		Pinyon-Juniper		Upland Sagebrush	
	Caged	Uncaged	Caged	Uncaged	Caged	Uncaged
Cryptantha sericea	1.6	1.4	2.9	3.1	2.6	2.1
Cryptantha spp.						0.1
Eriogonum lonchophyllum	9.1	1.8	1.7	5.9		
Eriogonum umbellatum	12.8	9.1		0.4		0.5
Haplopappus acaulis					1.4	
Haplopappus nuttallii	3.7	3.5	5.0	9.0	6.8	1.1
Hedysarum boreale	40.0	6.9				
Heterotheca villosa	4.4	3.3	1.2	0.3	1.5	1.7
Heuchera parviflora	0.6	0.4				
Hymenoxys acaulis	0.4	0.6			0.4	
Ipomopsis aggregata	0.5	0.6		0.3	0.1	0.2
Linum lewisii	1.4	0.9		0.1		0.4
Lithospermum ruderale	0.6	1.1				
Lupinus argenteus	13.0	9.0			7.2	9.9
Lupinus spp.					2.6	1.7
Penstemon caespitosus	5.2	4.0	0.2	0.2	1.7	1.2
Phlox longifolia	2.3	1.2	0.6		3.2	2.5
Physaria floribunda	1.3	1.0	0.8	1.1	0.4	0.3
Salsola kali		0.1		0.3		
Senecio multilobatus			0.7	0.3	0.1	0.2
Senecio spp.						0.1
Sphaeralcea coccinea	2.3	0.8		0.4	4.5	2.1
Unknown composite	0.6	5.7	1.8	0.3	1.9	0.2
Unknown forb	0.02	0.1	1.6	0.7	0.2	0.2
Total Forbs (kg/ha)	132.1	90.6	29.7	30.0	61.4	37.3
Total Grass & Forbs (kg/ha)	291.2	202.1	73.1	66.1	218.3	131.2

1/ Differences in the number of plots sampled (N) result when caged plots have been disturbed and consequently do not function as protected sample locations.

a. Mixed Brush - Average production within caged plots was 291.2 kg/ha during 1980. Grasses accounted for 159.1 and forbs for 132.1 kg/ha (Table 3-4). Agropyron spp., Oryzopsis hymenoides, and Poa spp. species were dominant, accounting for 82.3, 39.6, and 29.7 kg/ha respectively. These three genera accounted for 95 percent of total grass production. Comandra umbellata, Eriogonum spp., Hedysarum boreale, and Lupinus argenteus species accounted for 70 percent of the forb production. Respective biomass values were 17.9, 21.9, 40.0, and 13.0 kg/ha.

Analysis of the 1980 data from the mixed brush vegetation type indicated that there were significant differences in both grass and forb production (caged plots) among the 10 transects sampled (Table 3-5). Duncan's multiple range test results illustrate these differences (Table 3-6). Grass and forb production was significantly different between transects 35 and 36, but most of the remaining transect groupings were not significantly different. Transect 35 exhibited the highest production of both grasses and forbs whereas transect 36 had the lowest. Field observation suggests that transect 36 is in an ecotonal area and should be categorized in the pinyon-juniper vegetation type or deleted from the sampling program. The site supports mature pinyon pine and juniper trees, and is located near a ridge top on moderate terrain, with an easterly exposure. Mixed brush stands on Tract C-a and vicinity typically have fewer, less mature trees, and are located on steep, north-facing slopes.

Production during 1980 (291 kg/ha) exceeded that of 1978 or 1979 (210 and 244 kg/ha, respectively) (Table 3-7). Estimates for production during 1975 and 1977 (233 and 275 kg/ha, respectively), based on different sample locations and/or methods, were also lower than those for 1980 (RBOSC 1980a). With the exception of lupine (Lupinus spp.) production, which was approximately three times that of 1979, the dominant grass and forb species encountered during 1980 were the same as those reported for 1979. Similarities also were noted for 1978 data; however, Koeleria gracilis was more prevalent in 1978 than in 1979 or 1980 (RBOSC 1979b).

Although the interaction effect (year x plot type) of the two-way ANOVA showed no significant difference, the main effects for year and plot type indicated significant differences in grass production for 1978 through 1980 (Table 3-8). These significant differences are illustrated by the Duncan's multiple range

Table 3-5. Summary of One-way ANOVA Results Comparing Range Productivity Within Vegetation Types for 1980, Tract C-a[1/]

Vegetation Type	Caged		Uncaged	
	F	PR>F[2/]	F	PR>F[2/]
Mixed Brush				
Grasses	2.24*	0.0241	1.50	0.1575
Forbs	2.38*	0.0144	1.75	0.0812
Pinyon-Juniper				
Grasses	3.52*	0.0011	1.72	0.1011
Forbs	4.62*	0.0002	3.12*	0.0049
Upland Sagebrush				
Grasses	3.13*	0.0022	1.11	0.3585
Forbs	0.68	0.7291	0.48	0.8644

*Significant at $\alpha = 0.05$

[1/] Complete analyses are presented in Appendix 3-1.4

[2/] PR>F represents the significance probability (α) associated with F

Table 3-6. Results of Duncan's Multiple Range Tests for Significant Main Effect Differences in 1980 Grass and Forb Production (kg/ha) Within Caged Plots on Transects in the Mixed Brush Vegetation Type, Tract C-a

VEG TYPE=MIXED BRUSH GR FRM=GRASSES PLT TYPE=CAGED

GENERAL LINEAR MODELS PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE KG HA
MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=118 MS=4702.18

GROUPING	MEAN	N	TRANSECT
A	117.230769	13	35
A			
B A	86.384615	13	32
B A			
B A C	76.307692	13	31
B A C			
B A C	71.125000	8	34
B C			
B C	58.357143	14	3
B C			
B C	57.750000	16	1
B C			
B C	51.900000	10	2
B C			
B C	43.352941	17	33
B C			
B C	36.333333	12	4
C			
C	13.000000	12	36

VEG TYPE=MIXED BRUSH GR FRM=FORBS PLT TYPE=CAGED

ALPHA LEVEL=.05 DF=182 MS=4480.9

GROUPING	MEAN	N	TRANSECT
A	96.333333	9	35
A			
B A	75.636364	22	3
B			
B C	35.050000	20	4
C			
C	32.482759	29	31
C			
C	30.722222	18	2
C			
C	21.880000	25	1
C			
C	18.117647	17	33
C			
C	17.714286	21	34
C			
C	17.300000	20	32
C			
C	16.090909	11	36

Table 3-7. Comparison of Range Production (standing crop, dry weight, kg/ha) and Utilization (%) Estimates on and Near Tract C-a, 1978 through 1980[1/]

Vegetation Type	Standing Crop: Caged Plots (dry wt, kg/ha) 1978	1979	1980	Standing Crop: Uncaged Plots (dry wt, kg/ha) 1978	1979	1980	Utilization (%) 1978	1979	1980
Mixed Brush (N)[2/]	(50)	(50)	(49)	(50)	(50)	(50)			
Grasses	99	140	159	69	85	111	30	39	30
Forbs	111	104	132	77	88	91	31	15	31
Total	210	244	291	146	173	202	30	29	31
Pinyon-Juniper (N)[2/]	(50)	(49)	(50)	(50)	(46)	(50)			
Grasses	26	34	43	13	26	36	50	24	16
Forbs	18	18	30	10	18	30	44	0	0
Total	44	52	73	23	44	66	48	15	10
Upland Sagebrush (N)[2/]	(50)	(50)	(49)	(50)	(48)	(50)			
Grasses	85	132	157	51	78	94	40	41	40
Forbs	40	42	62	29	29	37	28	31	40
Total	125	174	219	80	107	131	36	39	40

[1/] Production values reported for the 1979 sample period on Table 3-4 of the MDP Monitoring Report 5 were incorrectly transferred from Table 3-3 in the referenced report. These values have been corrected herein. Differences between the aforementioned report and this table for percent utilization during 1979 are due in part to this error in data transfer. Other slight differences are resultant from use of recalculated correction factors, deletion of several shrub species from the analyses, and/or rounding of figures.

[2/] Differences in the number of plots sampled (N) result when caged plots have been disturbed and consequently do not function as protected sample locations.

Table 3-8. Summary of Two-way ANOVA Results Comparing Range Productivity for 1978 through 1980, Tract C-a[1/]

Vegetation Type	Source of Variation: Between Years F	Between Years PR>F[2/]	Caged vs. Uncaged F	Caged vs. Uncaged PR>F[2/]	Year x Plot Type F	Year x Plot Type PR>F[2/]
Mixed Brush						
Grasses	6.31*	0.0019	9.20*	0.0025	0.48	0.6190
Forbs	0.30	0.7383	0.81	0.3691	1.02	0.3600
Pinyon-Juniper						
Grasses	7.02*	0.0010	9.43*	0.0023	1.39	0.2495
Forbs	0.60	0.5486	0.04	0.8401	0.23	0.7959
Upland Sagebrush						
Grasses	9.77*	0.0001	17.23*	0.0001	0.84	0.4332
Forbs	0.53	0.5877	1.99	0.1588	0.19	0.8268

*Significant at $\alpha = 0.05$

[1/] Complete analyses are presented in Appendix 3-1.4

[2/] PR>F represents the significance probability (α) associated with F

test results presented on Table 3-9. The variation for plot type was expected because the uncaged plots were subject to grazing. The lack of significant difference between plot types for forb species would suggest that forbs are not being as heavily grazed as grasses.

The high degree of variation between plot types (Table 3-8) may be influencing the test for main effect, year, since both plot types are lumped within years in this two-way ANOVA. However, a one-way ANOVA comparing only caged plots (Table 3-10) indicates that the main effect year is significant for grass species at the 5.68 percent level. Forb production was not significantly different between years. Mean production of grasses (caged plots) during 1978 was significantly lower than in either 1980 or 1979 (Table 3-11).

Utilization of herbaceous species within the mixed brush vegetation type was 31 percent during 1980. As shown on Table 3-7, there is only slight variability in utilization from 1978 to 1980. Utilization for 1977 (56 percent) was considerably above that recorded during the 1978-1980 interval (RBOSC 1980a). During 1979, use of grass species was 23 percent higher than 1978 or 1980, but was only three-fifths of the 65 percent utilization recorded in 1977. Forb utilization for 1979 was one-half that reported for 1978 or 1980 and one-third of that experienced in 1977.

Between 1978 and 1980 range production has increased while utilization has remained relatively constant. With the inclusion of 1977 data, which may not be strictly comparable due to different sampling locations, both production and utilization fluctuations become more evident. It is probable that some variation in production results from differences in available moisture between years. However, it remains unclear whether variations in utilization result from normal fluctuations in wildlife populations and/or livestock grazing pressure, or from tract activities.

b. Pinyon-Juniper - Production within caged plots averaged 73.1 kg/ha for the 1980 sample period (Table 3-4). Grass species contributed 43.4 kg/ha, approximately 60 percent of the total. Poa species were dominant (16.8 kg/ha), but Agropyron and Oryzopsis species also were prevalent (8.6 and 9.1 kg/ha, respectively). Balsamorhiza sagittata and Haplopappus nuttallii were the most

Table 3-9. Results of Duncan's Multiple Range Tests for Significant Main Effect Differences, Year and Plot Type, in Grass Production for 1978, 1979 and 1980 Within the Mixed Brush Vegetation Type, Tract C-a

VEG TYPE=MIXED BRUSH GR FRM=GRASSES

GENERAL LINEAR MODELS PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE KG HA

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=697 MS=4130.13

GROUPING	MEAN	N	YEAR
A	54.354967	246	80
A			
A	51.664562	218	79
B	35.056180	239	78

VEG TYPE=MIXED BRUSH GR FRM=GRASSES

GENERAL LINEAR MODELS PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE KG HA

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=697 MS=4130.13

GROUPING	MEAN	N	PLT TYPE[1/]
A	54.040388	365	Y
B	39.313259	338	N

[1/] Plot type 'Y' signifies a caged plot and 'N' an uncaged plot

Table 3-10. Summary of One-way ANOVA Results Comparing Range Production Within Caged Plots by Vegetation Type, 1978 Through 1980, Tract C-a[1/]

Vegetation Type	Source of Variation: Years F	Years PR>F[2/]
Mixed Brush		
Grasses	2.89	0.0568
Forbs	0.20	0.8191
Pinyon-Juniper		
Grasses	1.49	0.2270
Forbs	0.23	0.7970
Upland Sagebrush		
Grasses	5.45*	0.0047
Forbs	0.23	0.7969

* Significant at $\alpha = 0.05$

[1/] Complete analyses are presented in Appendix 3-1.4

[2/] PR>F represents the significance probability (α) associated with F

Table 3-11. Results of a Duncan's Multiple Range Test for Significant Main Effect Differences Between Years in Grass Production within Caged Plots of the Mixed Brush Vegetation Type, Tract C-a

VEG TYPE=MIXED BRUSH GR FRM=GRASSES

GENERAL LINEAR MODELS PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE KG HA

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=362 MS=6660.96

GROUPING	MEAN	N	YEAR
A	61.955752	113	79
A			
A	60.914062	128	80
B	39.731787	124	78

common forbs, contributing 10.1 and 5.0 kg/ha, respectively. The total for these species represents 51 percent of forb production, which averaged 29.7 kg/ha. The dominant grass and forb species reported herein also were encountered during 1978 and 1979 but typically exhibited lower production during those periods (RBOSC 1979b, 1980a).

Significant differences in grass and forb production were noted among the 10 pinyon-juniper transects sampled during 1980 (Table 3-5). Duncan's multiple range test results illustrating these significant main effect differences are presented on Table 3-12. Transects 6, 19, and 17 had significantly higher grass production than the remaining seven sites. Forb production among transects exhibited even greater variability than grasses. Based on 1980 data, transect 37 was shown to have significantly higher forb production than any of the other sites. These data illustrate the variability which is characteristic of the pinyon-juniper vegetation type in the vicinity of Tract C-a. On occasions when randomly placed range cages fall on densely vegetated plots this natural variability is accentuated. The 1980 data illustrate this phenomenon. On transect 37, one of only two forbs encountered within caged plots was Balsamorhiza, which had a standing crop of 50.7 g/m^2 (507 kg/ha) (Appendix 3-1.3). Consequently, the average forb production for the transect was very high relative to other pinyon-juniper transects where this species did not occur in the plots. A similar event occurred on transect 6 where Sitanion hystrix was encountered in only one caged plot at a rate of 132 kg/ha.

Differences in standing crop for uncaged plots generally were not significant for the three vegetation types. However, in the case of forbs in the pinyon-juniper type, there were significant differences (Table 3-5). Table 3-13 illustrates that transects 37 and 6 had a significantly greater standing crop of forbs on uncaged plots than did any of the remaining eight transects. On transect 37 this difference is probably a function of arrowleaf balsam root (Balsamorhiza sagittata) as noted above. Estimated standing crop on transect 6 exceeded that of caged plots. This may occur in situations where random cage placement and subsequent correction factor determinations are based on inordinately dense or sparce stands, and/or where grazing pressure is light.

Table 3-12. Results of Duncan's Multiple Range Tests for Significant Main Effect Differences in 1980 Grass and Forb Production Within Caged Plots on Transects in the Pinyon-Juniper Vegetation Type, Tract C-a

VEG TYPE=PINYON-JUNIPER GR FRM=GRASSES PLT TYPE=CAGED

GENERAL LINEAR MODELS PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE KG HA
MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=78 MS=491.674

GROUPING	MEAN	N	TRANSECT
A	56.000000	3	6
A			
A	50.500000	8	19
A			
A	45.125000	8	17
B	22.600000	10	7
B			
B	21.272727	11	12
B			
B	20.714286	7	5
B			
B	17.888889	9	37
B			
B	16.375000	8	11
B			
B	15.750000	12	16
B			
B	12.666667	12	40

VEG TYPE=PINYON-JUNIPER GR FRM=FORBS PLT TYPE=CAGED

ALPHA LEVEL=.05 DF=51 MS=2815.03

GROUPING	MEAN	N	TRANSECT
A	255.500000	2	37
B	40.000000	6	6
B			
B	31.333333	6	19
B			
B	15.166667	6	40
B			
B	14.900000	10	16
B			
B	14.200000	5	11
B			
B	13.111111	9	17
B			
B	8.700000	10	12
B			
B	4.400000	5	5
B			
B	3.000000	2	7

Table 3-13. Results of a Duncan's Multiple Range Test for Significant Main Effect Differences in 1980 Forb Biomass as Estimated Within Uncaged Plots on Trasects in the Pinyon-Juniper Vegetation Type, Tract C-a

VEG TYPE=PINYON-JUNIPER GR FRM=FORBS PLT TYPE=UNCAGED

GENERAL LINEAR MODELS PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE KG HA

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=48 MS=1697.41

GROUPING	MEAN	N	TRANSECT
A	89.337349	3	37
A			
A	82.357869	8	6
B	25.824078	8	5
B			
B	12.283886	10	17
B			
B	10.469221	8	12
B			
B	9.771273	4	19
B			
B	9.305974	6	11
B			
B	8.514966	8	16
B			
B	5.583584	1	7
B			
B	5.583584	2	40

Data for 1978 through 1980 indicate that mean production has increased from 44 to 73 kg/ha (Table 3-7). Grasses seem to have increased uniformly during the period. Forb production remained the same during 1978 and 1979, and exhibited a marked increase during 1980. Total production for 1977 (75 kg/ha), as based on data from different sample locations, was similar to that for 1980. During 1975, total production within the pinyon-juniper type (113 kg/ha) was the highest recorded for the vegetation type (RBOSC 1980a). With the exception of Balsamorhiza, dominant species encountered during 1980 were the same as previous years. As noted above, Balsamorhiza production was much higher during 1980.

Two-way ANOVA indicate significant differences for grass production between main effects (years and plot types). The interaction effect (year x plot type) was not significant for either grasses or forbs (Table 3-8). Significant differences are presented on Table 3-14 using Duncan's multiple range tests. These tests show that the pinyon-juniper data are similar to data for the mixed brush type in that 1978 production of grasses (caged and uncaged plots) was significantly lower than 1979 or 1980. Significant differences between caged and uncaged plots are expected due to grazing. By testing the main effect year in a one-way ANOVA using only caged plots, it is evident that the significant difference is an artifact of the lumped plot types in the aforementioned two-way ANOVA (Table 3-10). Differences in grass production (caged plots) were significant only at the 22.7 percent level.

Utilization of herbaceous species within the pinyon-juniper vegetation type has decreased from 48 percent in 1978 to 10 percent in 1980 (Table 3-7). Data for 1979 and 1980 indicate zero use of forbs, and decreasing utilization of grasses from 24 percent in 1979 to 16 percent in 1980. Although it is probable that grasses are used much more heavily than are forbs, the zero percentage values noted for forb utilization may be an artifact of the sampling design and/or correction factor determination rather than complete lack of utilization. If 1975 and 1977 data are taken into consideration, utilization seems to have fluctuated during the 1975-1978 interval and then decreased considerably.

Decreased utilization may indicate lower grazing pressure from deer, feral horses, and livestock. It is unclear whether reduced grazing is a result of

Table 3-14. Results of Duncan's Multiple Range Tests for Significant Main Effect Differences, Year and Plot Type, in Grass Production Within the Pinyon-Juniper Vegetation Type, Tract C-a

VEG TYPE=PINYON-JUNIPER GR FRM=GRASSES

GENERAL LINEAR MODELS PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE KG HA

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=436 MS=432.544

GROUPING	MEAN	N	YEAR
A	23.787859	167	80
A			
A	19.799898	144	79
B	14.691655	131	78

TWO-WAY ANALYSIS OF VARIANCE

VEG TYPE=PINYON-JUNIPER GR FRM=GRASSES

GENERAL LINEAR MODELS PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE KG HA

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=436 MS=432.544

GROUPING	MEAN	N	PLT TYPE[1/]
A	22.735975	226	Y
B	16.713121	216	N

1/ Plot type 'Y' signifies a caged plot and 'N' an uncaged plot

normal population fluctuations or variations in use patterns. During the 1980 season, grazing allotments in the vicinity of RBOSC study sites were managed as a rest-rotation range unit (personal communication, R. Roberts, Bureau of Land Management, Meeker), resulting in lower grazing pressure than in previous years. In addition, during August-September, 1980 the BLM removed a number of feral horses from the area. Both factors should have resulted in changes in use patterns. It is possible that, with sufficient production of forage in both the mixed brush and upland sagebrush types, the remaining grazers used these types in preference to the pinyon-juniper vegetation type. Furthermore, in portions of the study area where RBOSC has revegetated disturbed areas, livestock and/or feral horses may be drawn away from their normal grazing patterns by the readily accessible forage on the revegetated sites. This has been evident in the access road sand pit at the northeast corner of Tract C-a.

c. Upland Sagebrush - Forage production averaged 218.3 kg/ha during 1980. Grasses accounted for 156.9 while forbs contributed 61.4 kg/ha (Table 3-4). Agropyron, Bromus tectorum, Oryzopsis, and Poa were the dominant grass species encountered, with respective production values of 75.2, 30.1, 14.2 and 23.0 kg/ha. The aforementioned species accounted for 91 percent of all grass production in the upland sagebrush vegetation type. The most prominent species contributing to forb production were Astragalus, Comandra, Haplopappus, and Lupinus. Respective biomass values for these species were 13.4, 6.5, 6.8, and 9.8 kg/ha, which accounted for 59 percent of total forb production. With the exception of Bromus, biomass values for these grass and forb species are similar to those encountered during previous years. Production of cheat-grass (Bromus tectorum) recorded for 1980 was approximately three to four times that of 1979 or 1978 (RBOSC 1979b, 1980a).

Comparison of the 10 upland sagebrush transects (caged plots) sampled during 1980 indicates that there are significant differences among transects for grass production (Table 3-5). Duncan's multiple range test results illustrate that transects 15 and 28 are similar to transect 20 but significantly different from the remaining seven transects (Table 3-15). Because transects 15 and 28 are located in valley bottom sites, this variation may be related more to location than to variability within the upland sagebrush vegetation type. Transect 14 also is located on a valley bottom site but its grass production does not

Table 3-15. Results of a Duncan's Multiple Range Test for Significant Main Effect Difference in 1980 Grass Production Within Caged Plots on Transects in the Upland Sagebrush Vegetation Type, Tract C-a

VEG TYPE=UPLAND SAGEBRUSH GR FRM=GRASSES PLT TYPE=CAGED

GENERAL LINEAR MODELS PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE KG HA

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=114 MS=6888.79

GROUPING	MEAN	N	TRANSECT
A	147.833333	12	15
A			
A	136.200000	10	28
A			
B A	78.250000	8	20
B			
B	58.266667	15	14
B			
B	49.444444	9	10
B			
B	46.615385	13	30
B			
B	41.411765	17	22
B			
B	39.363636	11	39
B			
B	35.200000	15	8
B			
B	24.000000	14	38

differ significantly from that of upland sites. The increased production noted for transects 15 and 28 seems to be due to cheat-grass and squirreltail which are more prevalent there than in upland locations. The abundance of these species in valley bottom sites is probably related to the greater degree of disturbance from livestock grazing. Transects 15 and 28 would be categorized more appropriately within a valley bottom sagebrush vegetation type.

Total production within the upland sagebrush type has increased from 125 kg/ha in 1978 to 219 kg/ha in 1980 (Table 3-7). Forb production increased 35 percent over the three year period whereas grasses increased 46 percent. Data from 1975 and 1977, based on different sample locations and/or techniques, show that 1977 production (125 kg/ha) was similar to that of 1978. Total production for 1975 (302 kg/ha) was higher than production within any vegetation type for five years of study (RBOSC 1980a). The increase in production between 1978 and 1980 may be a result of more favorable environmental conditions. This supposition is supported by data from the other vegetation types, all of which exhibited increases in total production for the same period.

Significant variations in grass production for main effects, year and plot type, were noted in the upland sagebrush vegetation type (Table 3-8). The interaction effect (year x plot type) was not significant. The significant main effects are illustrated by Duncan's multiple range test results presented on Table 3-16. As noted for the other vegetation types, grass production (both caged and uncaged plots) was significantly lower in 1978 than in either 1979 or 1980. As expected, standing crop in caged plots was shown to be significantly greater than in unprotected plots. By testing only caged plots for main effect year, it was demonstrated that the significant difference in grass production indicated in the two-way ANOVA was valid (Table 3-10). Results of this comparison are illustrated by the Duncan's multiple range test results shown on Table 3-17.

Utilization of both grasses and forbs within the upland sagebrush vegetation type was 40 percent (Table 3-7). The rate of utilization has increased slightly from the 36 and 39 percent values reported for 1978 and 1979 respectively. Utilization for 1977 (41%, based on different sample sites and/or methods) was comparable to the 1980 data; however, estimated 1975 use (8%) was markedly lower (RBOSC 1980a). These results are similar to those reported for

Table 3-16. Results of Duncan's Multiple Range Tests for Significant Main Effect Differences, Year and Plot Type, in Grass Production Within the Upland Sagebrush Vegetation Type, Tract C-a

TWO-WAY ANALYSIS OF VARIANCE

VEG TYPE=UPLAND SAGEBRUSH GR FRM=GRASSES

GENERAL LINEAR MODELS PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE KG HA

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=683 MS=3441.38

GROUPING	MEAN	N	YEAR
A	50.526928	245	80
A			
A	49.158494	211	79
B	29.041327	233	78

TWO-WAY ANALYSIS OF VARIANCE

VEG TYPE=UPLAND SAGEBRUSH GR FRM=GRASSES

GENERAL LINEAR MODELS PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE KG HA

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=683 MS=3441.38

GROUPING	MEAN	N	PLT TYPE 1/
A	51.510112	360	Y
B	33.357230	329	N

1/ Plot type 'Y' signifies a caged plot and 'N' an uncaged plot

Table 3-17. Results of a Duncan's Multiple Range Test for Significant Main Effect Difference Between Years for Grass Production Within Caged Plots of the Upland Sagebrush Vegetation Type, Tract C-a

VEG TYPE=UPLAND SAGEBRUSH GR FRM=GRASSES

GENERAL LINEAR MODELS PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE KG HA

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=357 MS=5481.69

GROUPING	MEAN	N	YEAR
A	62.000000	124	80
A			
A	59.621622	111	79
B	33.901124	125	78

the mixed brush vegetation type in that use rates remained relatively constant between 1978-1980. It is unclear why there was a marked decrease in utilization in the pinyon-juniper type and no prominent change in the other vegetation types.

D. Browse

1. Objectives

Tract C-a development will reduce browse availability and therefore may affect the distribution of deer in the vicinity of Tract C-a. The browse condition and utilization studies are designed to provide browse use information for areas adjacent to Tract C-a development.

2. Methods

The methods for collection of browse data were described in RBOSC MDP Monitoring Reports 1 and 2 (RBOSC 1978a, 1978b). Transects are the same as those for range productivity studies, with transect PJ 40 replacing PJ 18 (Figure 3-1). With a few exceptions, the individual plants censused in 1980 were the same ones assessed for browse condition in all previous sampling periods. Browse condition for 1980 was assessed between April 29 and May 16, 1980.

Leader use values (%) for each species within three vegetation types were arcsine transformed and analyzed by the following two-way ANOVA.

	Source of Variation	Degrees of Freedom	F-Test
A.	Year (phase of development)	a-1	A/D
B.	Transect	b-1	B/D
C.	Year x Transect	(a-1)(b-1)	C/D
D.	Error	ab(n-1)	
	Total	abn-1	

3. Results and Discussion

Data obtained during the 1980 sampling period are summarized in Table 3-18 and listed in their entirety in Appendix 3-1.1 of MDP Monitoring Report 6 (RBOSC 1980b).

a. Mixed Brush - All individual shrubs assessed for browse condition and utilization during 1979 were sampled again during spring 1980. Mountain mahogany (Cercocarpus montanus) was most heavily utilized (21.2% average based on 13 living individuals) whereas snowberry (Symphoricarpos oreophilus) was least heavily utilized (0.6% average for 39 living shrubs) (Table 3-18). Browse use of serviceberry (Amelanchier utahensis), the most prominent species encountered on mixed brush transects, was 3.3 percent during 1980 (based on 115 individuals). Sagebrush (Artemisia tridentata) and pinyon pine (Pinus edulis) had respective use values of 5.2 and 5.8 percent (based on 55 and 6 living individuals, respectively).

Two-way ANOVA comparing leader use from 1978 through 1980 indicate significant interaction effects (year x transect) for both serviceberry and snowberry (Table 3-19). Significant main effect differences between years were noted for serviceberry and mountain mahogany. All species except pinyon pine exhibited significant differences among transects. Variations among years reflect apparent changes in overall utilization while differences among transects suggest variation in use patterns within the study area. If significant main effect differences are not accompanied by a corresponding significant interaction effect (year x transect) it is expected that main effect changes are not uniform.

Utilization of serviceberry was significantly lower in 1980 than during either 1978 or 1979 (Table 3-20). Most differences among transects (main effect) for serviceberry leader use were not significant. However, shrubs on transect 31 exhibited significantly lower use than those on transect 34. Although 1980 leader use for mountain mahogany was not significantly different from either 1978 or 1979, the results of a Duncan's multiple range test indicate that use was significantly higher in 1979 than in 1978 (Table 3-21). Mountain mahogany

Table 3-18. Condition of Important Browse Species in Three Vegetation Types During April-May 1980 in the Vicinity of RBOSC Oil Shale Tract C-a[1/]

Habitat Type[2/]	Species	Number of Plants Sampled	Ave. Util. (%)	Ave. Avail. (%)	Form Class (%)[3/]								Age Class (%)				Hedging Class (%)		
					1	2	3	4	5	6	7	8	Seedling	Young	Mature	Decadent	Light	Moderate	Severe
MB	Serviceberry	128	3.3	77.7	32	12	7	16	16	7	..	10	1	5	51	44	50	34	17
	Sagebrush	61	5.2	81.4	30	21	..	11	21	7	..	10	..	..	66	34	44	49	7
	Snowberry	41	0.6	70.0	37	5	2	24	20	5	2	5	2	12	37	49	69	26	5
	Mountain Mahogany	14	21.2	85.0	14	36	14	7	7	14	..	7	14	..	57	29	23	46	31
	Pinyon Pine	6	5.8	88.3	50	33	..	17	..	..	..	..	..	..	83	17	67	33	..
PJ	Sagebrush	105	8.8	71.1	17	10	5	14	20	21	12	..	1	..	46	53	34	38	28
	Pinyon Pine	51	4.5	53.1	27	4	4	33	12	..	14	6	4	6	80	10	71	25	4
	Juniper	47	0.1	36.1	21	..	..	40	9	2	15	13	..	2	79	19	85	12	2
	Bitterbrush	23	34.5	68.3	4	17	13	4	26	26	..	9	..	..	43	57	10	48	43
	Mountain Mahogany	17	40.6	69.7	..	..	12	..	6	82	..	..	..	..	65	35	..	..	100
	Snowberry	4	1.7	73.3	..	25	50	..	..	..	..	25	..	..	50	50	33	..	67
	Serviceberry	3	1.7	33.3	..	33	..	33	..	33	..	..	..	..	33	67	33	..	67
SB	Sagebrush	235	1.1	75.3	13	13	3	15	16	13	..	26	..	..	46	54	38	45	17
	Serviceberry	10	0.6	95.6	60	20	..	10	..	..	..	10	..	30	60	10	89	11	..
	Snowberry	4	0.0	50.0	..	25	..	..	75	..	..	..	..	..	25	75	..	100	..
	Pinyon Pine	1	0.0	100.0	100	..	..	..	..	..	..	..	..	..	100	..	100	..	..

1/ .. indicate no individuals present in this category

2/ MB = Mixed Brush
PJ = Pinyon-Juniper
SB = Sagebrush

3/

Form Classes

1 All available, little or no hedging
2 All available, moderately hedged
3 All available, severely hedged
4 Partially available, little or no hedging
5 Partially available, moderately hedged
6 Partially available, severely hedged
7 Unavailable
8 Dead

Table 3-19. Summary of Two-way ANOVA Results Comparing Browse Leader Use from 1978 through 1980, Tract C-a[1/]

Habitat Type	Species	Source of Variation: Year F	Year PR>F[2/]	Among Transects F	Among Transects PR>F[2/]	Year x Transect F	Year x Transect PR>F[2/]
MB	Serviceberry	10.87*	0.0001	7.26*	0.0001	2.52*	0.0007
	Sagebrush	0.18	0.8391	3.28*	0.0047	1.59	0.0991
	Snowberry	2.42	0.0949	6.24*	0.0001	4.33*	0.0001
	Mountain Mahogany	3.53*	0.0412	6.92*	0.0130	0.90	0.4162
	Pinyon Pine	0.37	0.0739	1.68	0.2685	0.25	0.9422
PJ	Sagebrush	10.39*	0.0001	1.97*	0.0428	2.92*	0.0004
	Pinyon Pine	4.30*	0.0161	4.37*	0.0001	1.27	0.2241
	Juniper	1.15	0.3232	0.92	0.5219	1.05	0.4207
	Bitterbrush	41.24*	0.0001	2.47*	0.0324	1.42	0.1988
	Mountain Mahogany	34.71*	0.0001	2.23	0.1206	0.18	0.9484
	Snowberry[3/]	4.44	0.0569	---	---	---	---
	Serviceberry	1.08	0.4812	1.07	0.4100	0.60	0.6254
SB	Sagebrush	118.13*	0.0001	9.13*	0.0001	7.63*	0.0001
	Serviceberry	1.69	0.2177	1.22	0.3448	0.53	0.8200
	Snowberry[4/]	---	---	---	---	---	---
	Pinyon Pine[4/]	---	---	---	---	---	---

* significant at $\alpha = 0.05$

1/ Complete analyses are presented in Appendix 3-1.5

2/ PR>F represents the significance probability (α) associated with F

3/ Species present only on one transect, therefore source of variation occurs only among years

4/ No leader use was noted

Table 3-20. Results of Duncan's Multiple Range Tests for Significant Main Effect Differences, Year and Transect, in Serviceberry Leader Use for 1978, 1979 and 1980 Within the Mixed Brush Vegetation Type, Tract C-a

TWO-WAY ANALYSIS OF VARIANCE FOR BROWSE UTILIZATION

HABITAT=MB SPECIES=AME UTA

GENERAL LINEAR MODELS PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE ASLU

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=328 MS=0.010903

GROUPING	MEAN	N	YEAR
A	0.089812	125	78
A			
A	0.086451	118	79
B	0.033152	115	80

ALPHA LEVEL=.05 DF=328 MS=0.010903

GROUPING	MEAN	N	TRANSECT
A	0.161085	51	34
A			
B A	0.105349	13	33
B			
B	0.089346	30	6
B			
B	0.087732	21	4
B			
B	0.074416	36	2
B			
B	0.069334	37	1
B			
B C	0.048886	50	35
B C			
B C	0.044949	37	32
B C			
B C	0.042972	18	3
C			
C	0.015498	65	31

Table 3-21. Results of Duncan's Multiple Range Tests for Significant Main Effect Differences, Year and Transect, in Mountain Mahogany Leader Use for 1978, 1979 and 1980 Within the Mixed Brush Vegetation Type,Tract C-a

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TWO-WAY ANALYSIS OF VARIANCE FOR BROWSE UTILIZATION

HABITAT=MB SPECIES=CER MON

GENERAL LINEAR MODELS PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE ASLU

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=32 MS=.0719032

GROUPING	MEAN	N	YEAR
A	0.411979	12	79
A B A	0.219046	13	80
B B	0.132197	13	78

ALPHA LEVEL=.05 DF=32 MS=.0719032

GROUPING	MEAN	N	TRANSECT
A	0.313325	30	6
B	0.013771	8	35

---

has limited occurrence on only two transects (6 and 35) so that the aforementioned differences may not be indicative of major variations in use pattern. Artemisia and Symphoricarpos, on the other hand, are more prevalent within the mixed brush transects and significant variations among transects for these species are illustrated on Table 3-22. Sagebrush use on transects 33 and 34 was significantly greater than on four of five remaining transects where it was encountered. Leader use for snowberry was significantly greater on transect 6 than on eight of the other transects where it occurred.

The weighted average utilization for all species within the mixed brush habitat was four percent, or approximately half that experienced in 1979 or 1978 (Table 3-23). Much of this reduction seems to be related to the significantly lower use of serviceberry. With reduced useage in 1980, all of the species sampled in the mixed brush habitat have "acceptable" use rates for "mild" winter conditions (Cole 1963). During the 1979 season use was judged "acceptable" for "average" winter conditions.

Table 3-23. Comparison of Weighted Average Utilization (in percent) in Three Vegetation Types During April 1976, May 1977, May 1978, May 1979, and May 1980 on and Near Tract C-a[1/]

Vegetation Type	April 1976	April 1977	May 1978	May 1979	May 1980
Mixed Brush	12	17	7	8	4
Pinyon-Juniper	27	24	31	15	10
Upland Sagebrush[2/]		6	25	4	1

[1/] N = 250

[2/] Data not available for 1976

Distribution of individual shrubs by form class varied only slightly from 1979 data (Table 3-18). Seven mountain mahogany plants which appeared to have died in 1979 resprouted in 1980. Two serviceberry shrubs died between sample periods.

Table 3-22. Results of Duncan's Multiple Range Tests for the Significant Main Effect Difference, Transect, in Sagebrush and Snowberry Leader Use for 1978, 1979 and 1980 Within the Mixed Brush Vegetation Type, Tract C-a

TWO-WAY ANALYSIS OF VARIANCE FOR BROWSE UTILIZATION

HABITAT=MB SPECIES=ART TRI

GENERAL LINEAR MODELS PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE ASLU

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=144 MS=.0407232

GROUPING	MEAN	N	TRANSECT
A	0.171821	27	33
A			
A	0.170927	20	34
A			
B A	0.085281	6	32
B			
B	0.031764	37	3
B			
B	0.015677	30	1
B			
B	0.013902	18	2
B			
B	0.003710	27	4

HABITAT=MB SPECIES=SYM ORE

ALPHA LEVEL=.05 DF=88 MS=.0107414

GROUPING	MEAN	N	TRANSECT
A	0.313558	6	6
B	0.030769	15	4
B			
B	0.012100	29	33
B			
B	0.011130	18	32
B			
B	0.000000	3	1
B			
B	0.000000	18	2
B			
B	0.000000	17	3
B			
B	0.000000	3	34
B			
B	0.000000	6	35

Based on age class distribution (Table 3-18) the mixed brush browse condition rating would be "good" for pinyon pine, "fair" for mountain mahogany, and "poor" for serviceberry, snowberry, and sagebrush (Cole 1963). Similar condition ratings based on hedging class indicate that pinyon pine, sagebrush, and snowberry are in "excellent" condition, serviceberry "good", and mountain mahogany "poor". These ratings are similar to those evidenced during 1979.

b. Pinyon-Juniper - Variations in the number of individuals of each species sampled for the pinyon-juniper habitat between 1979 and 1980 are a result of the replacement of transect PJ 18 with PJ 40. Use of transect PJ 40 resulted in a gain of two sagebrush, one pinyon pine, and ten juniper individuals and a reduction of 13 bitterbrush shrubs. The total number of shrubs sampled within the pinyon-juniper vegetation type is still 250.

Browse utilization in the pinyon-juniper vegetation type ranged from 0.1 percent for juniper (Juniperus osteosperma) (35 trees available for browse) to 40.6 percent for mountain mahogany (17 living shrubs) (Table 3-18). Sagebrush, the most abundant species encountered, had an average utilization of 8.8 percent on the 92 living individual shrubs which were assessed. Other species present included bitterbrush (Purshia tridentata) with 34.5, pinyon pine with 4.5, snowberry with 1.7, and serviceberry with 1.7 percent utilization. Respective numbers of available shrubs for these species were 21, 43, 3, and 3.

Sagebrush was the only species exhibiting a significant interaction effect (year x transect) for the pinyon-juniper vegetation type (Table 3-19). However, the main effect year was significant for pinyon pine, bitterbrush, and mountain mahogany, as well as sagebrush. Pinyon pine, bitterbrush, and sagebrush also exhibited significant main effect differences among transects.

Data indicate that utilization within the pinyon-juniper vegetation type has decreased since 1978. Although differences among transects do exist, concise patterns of change in leader use are not clear. The results of Duncan's multiple range tests show that use of sagebrush was significantly higher in 1978 than in 1979 or 1980 (Table 3-24). Variations in the use of sagebrush among transects over the three year period result in two groupings (Table 3-24). Transects 7, 16, and 18 are similar to five other sites but exhibited

Table 3-24. Results of Duncan's Multiple Range Tests for Significant Main Effect Differences, Year and Transect, in Sagebrush Leader Use for 1978, 1979 and 1980 Within the Pinyon-Juniper Vegetation Type, Tract C-a

TWO-WAY ANALYSIS OF VARIANCE FOR BROWSE UTILIZATION

HABITAT=PJ SPECIES=ART TRI

GENERAL LINEAR MODELS PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE ASLU

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=247 MS=.0728598

GROUPING	MEAN	N	YEAR
A	0.265570	91	78
B	0.124405	90	79
B			
B	0.095124	92	80

ALPHA LEVEL=.05 DF=247 MS=.0728598

GROUPING		MEAN	N	TRANSECT
	A	0.257973	32	37
	A			
	A	0.252283	37	19
	A			
B	A	0.248555	12	12
B	A			
B	A	0.175333	35	5
B	A			
B	A	0.138078	57	36
B	A			
B	A	0.132700	5	40
B	A			
B	A	0.129540	33	17
B				
B		0.078961	46	7
B				
B		0.064320	15	16
B				
B		0.000000	1	18

significantly lower use than at transects 19 and 37. Leader use of pinyon pine also was higher in 1978 than during 1979 or 1980 (Table 3-25). Transect 17 exhibited significantly higher leader use of pine than on all other sites within the vegetation type. Utilization for transects 18 and 19 was similar to transect 36 but significantly higher than seven other transects. Bitterbrush and mountain mahogany showed the same significant decreases in leader use between 1978 and subsequent sample periods (Tables 3-26, 3-27). There were no significant differences in use among transects for Cercocarpus. For bitterbrush utilization, transects 17 and 19 were similar to four other sites but exhibited significantly lower use than transect 11.

Average weighted utilization for all species of the pinyon-juniper vegetation type was 10 percent in 1980 as compared to 15 percent during 1979 (Table 3-23). As with the mixed brush habitat, the 1980 use is the lowest recorded since the studies began in 1976. Sagebrush utilization decreased from 11.7 in 1979 to 8.8 in 1980. Decreases also were evident for the less abundant pinyon pine, mountain mahogany, snowberry, and serviceberry individuals. Use of juniper remained unchanged, whereas bitterbrush utilization increased from 23.1 in 1979 to 34.5 percent in 1980. Browse use for all species of the pinyon-juniper habitat would be deemed "acceptable" for "mild" to "average" winter conditions (Cole 1963).

A large number of sagebrush, bitterbrush, mountain mahogany, snowberry, and serviceberry individuals were categorized as being in the decadent age class (Table 3-18). Based on the age class criterion, the aforementioned species have browse condition ratings of "poor" to "very poor" (Cole 1963). Pinyon pine and juniper have respective ratings of "excellent" and "good". Similar ratings were evident for most species when using hedging classification as the controlling factor. However, in this case sagebrush would be rated in "fair" condition while pine and juniper would both have "excellent" condition ratings. These ratings for the 1980 sample period show no major change from ratings evidenced during 1978 or 1979.

Table 3-25. Results of Duncan's Multiple Range Tests for Significant Main Effect Differences, Year and Transect, in Pinyon Pine Leader Use for 1978, 1979 and 1980 Within the Pinyon-Juniper Vegetation Type, Tract C-a

TWO-WAY ANALYSIS OF VARIANCE FOR BROWSE UTILIZATION

HABITAT=PJ SPECIES=PIN EDU

GENERAL LINEAR MODELS PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE ASLU

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=102 MS=.0524192

GROUPING	MEAN	N	YEAR
A	0.183182	45	78
B	0.078957	44	79
B			
B	0.046669	43	80

ALPHA LEVEL=.05 DF=102 MS=.0524192

GROUPING	MEAN	N	TRANSECT
A	0.744998	3	17
B	0.299441	8	18
B			
B	0.253039	17	19
B			
C B	0.184428	3	36
C			
C	0.075601	24	11
C			
C	0.067189	15	16
C			
C	0.047600	11	12
C			
C	0.035162	12	37
C			
C	0.017264	18	7
C			
C	0.008337	18	5
C			
C	0.003333	3	40

Table 3-26. Results of Duncan's Multiple Range Tests for Significant Main Effect Differences, Year and Transect, in Bitterbrush Leader Use for 1978, 1979 and 1980 Within the Pinyon-Juniper Vegetation Type, Tract C-a

TWO-WAY ANALYSIS OF VARIANCE FOR BROWSE UTILIZATION

HABITAT=PJ SPECIES=PUR TRI

GENERAL LINEAR MODELS PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE ASLU

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=67 MS=0.113429

GROUPING	MEAN	N	YEAR
A	0.993019	31	78
B	0.385538	21	80
B			
B	0.263329	33	79

ALPHA LEVEL=.05 DF=67 MS=0.113429

GROUPING		MEAN	N	TRANSECT
	A	0.709282	30	11
	A			
B	A	0.537474	21	37
B	A			
B	A	0.536561	24	18
B	A			
B	A	0.410663	3	16
B	A			
B	A	0.298293	3	12
B				
B		0.000000	2	17
B				
B		0.000000	2	19

Table 3-27. Results of a Duncan's Multiple Range Test for Significant Main Effect Differences Between Years in Mountain Mahogany Leader Use for 1978, 1979 and 1980 Within the Pinyon-Juniper Vegetation Type, Tract C-a

TWO-WAY ANALYSIS OF VARIANCE FOR BROWSE UTILIZATION

HABITAT=PJ SPECIES=CER MON

GENERAL LINEAR MODELS PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE ASLU

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=40 MS=0.127712

GROUPING	MEAN	N	YEAR
A	1.455486	15	78
B	0.664967	17	79
B			
B	0.443845	17	80

c. Sagebrush - All but one of the individual shrubs on the sagebrush transects were located and sampled during 1980. Plant number 25 on transect SB 22 could not be found and was replaced by a pinyon pine tree, the nearest appropriate individual. Consequently, one pinyon pine was added and one serviceberry deleted.

Utilization for the 173 living sagebrush plants assessed in the sagebrush vegetation type averaged 1.1 percent. Serviceberry was the only other species which received browse use (0.6 percent for nine individuals) (Table 3-18). Respective browse use of these species during 1979 was 3.9 and 3.3 percent. A statistical comparison of utilization between years and among transects (main effects) indicated significant differences for sagebrush but not for serviceberry (Table 3-19). The interaction effect (year x transect) also was significant for sagebrush. Sagebrush leader use was significantly lower during both 1979 and 1980 than during 1978 (Table 3-28). A similar trend was noted for sagebrush and three other species in the pinyon-juniper vegetation type. Variations in sagebrush leader use among transects for 1978 through 1980 result in five transect groupings (Table 3-28). Due to the complex nature of these groupings, trends in use pattern are not evident.

On the basis of weighted averages, 1980 leader use in the sagebrush vegetation type was only 25 percent of that noted in 1979 (Table 3-23). This decreased use follows a similar phenomenon noted for both the pinyon-juniper and mixed brush types. Lower browse use may reflect overall reduction in mule deer herd size, related to mortality during the 1979 winter season. A more detailed discussion of deer densities during the 1978-1980 period is presented in Section 3.2 of this report.

Fifty-four percent of the sagebrush plants censused was categorized in the decadent age class, resulting in a "very poor" range condition rating for that species (Table 3-18). The rating for snowberry was also "very poor". Only 10 percent of the serviceberry shrubs was classified as decadent, consequently Amelanchier received an "excellent" rating based on age class determinations (Cole 1963).

Table 3-28. Results of Duncan's Multiple Range Tests for Significant Main Effect Differences, Year and Transect, in Sagebrush Leader Use for 1978, 1979 and 1980 Within the Upland Sagebrush Vegetation Type, Tract C-a

TWO-WAY ANALYSIS OF VARIANCE FOR BROWSE UTILIZATION

HABITAT=SB SPECIES=ART TRI

GENERAL LINEAR MODELS PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE ASLU

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=511 MS=.0388189

GROUPING	MEAN	N	YEAR
A	0.298972	186	78
B	0.039711	182	79
B			
B	0.011391	173	80

ALPHA LEVEL=.05 DF=511 MS=.0388189

GROUPING			MEAN	N	TRANSECT
	A		0.227982	46	10
	A				
	A		0.226441	68	30
	A				
B	A		0.159859	60	38
B	A				
B	A	C	0.153140	44	8
B		C			
B	D	C	0.127646	56	20
B	D	C			
B	D	C	0.126461	55	15
	D	C			
E	D	C	0.070414	50	22
E	D				
E	D		0.063628	59	39
E					
E			0.020072	53	14
E					
E			0.003001	50	28

Sagebrush was the only species within this vegetation type with severely hedged individuals, and the condition rating for sagebrush was "good" based on Cole's (1963) rating scheme. Browse condition in the sagebrush vegetation type seems to have improved slightly from the 1979 status when condition was judged to be fair for both sagebrush and serviceberry.

3.2 FAUNA

A. Small Mammal Studies

1. Objectives and Rationale

The objectives of the small mammal program are to determine the species presence and habitat affinity, and to provide indices of relative abundance (captures/100 trap nights) of dominant small mammal species in sagebrush and pinyon-juniper habitats in control and treatment areas. Appreciable changes over time within these habitats are identified.

2. Methods

The methods followed for collection and analysis of these data were described in MDP Monitoring Report 5 (RBOSC 1978a) and are not repeated herein.

3. Results and Discussions

The numbers of small mammal species captured per 100 trap nights in the control and treatment habitats (Figure 3-1) during June 1979 and 1980 are presented in Table 3-29. Total small mammal captures for 1980 by date, habitat, area, transect and trap number are presented in Appendix 3-2.1. Small mammal trapping in 1980 was conducted along the same transects used in 1979 sampling.

The deer mouse (Peromyscus maniculatus) and the least chipmunk (Eutamias minimus) were the most frequently captured species during 1979 and 1980 in the pinyon-juniper and sagebrush habitats for both the control and treatment areas. These species were also captured most frequently over all habitats during baseline studies (RBOSP 1977). Other small mammal species captured included the longtail weasel (Mustela frenata) and bushytail woodrat (Neotoma cinerea) in 1979 and golden mantled ground squirrel (Citellus lateralis) and western harvest mouse (Reithrodontomys megalotis) in 1980. The limited species diversity may be a function of habitat quality or a function of the trap affinities of the various small mammal species in the area.

Table 3-29. Numbers of Small Mammal Species Live-trapped in Two Habitat Types in RBOSC Treatment Area 5 and Control Area 6 in 1979 and 1980[1/]

Species	Treatment Area 5				Control Area 6			
	Individuals[2/]		Total Captures[3/]		Individuals[2/]		Total Captures[3/]	
	1979	1980	1979	1980	1979	1980	1979	1980
Pinyon-Juniper Habitat								
Peromyscus maniculatus	8.33	11.11	17.22	18.32	31.11	18.32	55.55	38.30
Eutamias minimus	5.00	5.00	7.22	7.22	0.55	1.67	0.55	1.67
Neotoma cinerea[4/]	0.55		0.55					
Citellus lateralis[5/]		2.22		2.22				
Sagebrush Habitat								
Peromyscus maniculatus	22.22	13.22	41.66	24.42	34.44	9.99	61.66	21.09
Eutamias minimus	5.00	8.88	5.00	8.88	0.55	6.11	0.55	6.11
Mustela frenata[4/]					0.55		0.55	
Reithrodontomys megalotis[5/]						0.55		0.55

[1/] See Figure 3-1 for location of treatment and control areas

[2/] Number of separate individuals captured per 100 24-hour trapping periods

[3/] Number of total captures per 100 24-hour trapping periods

[4/] Species not captured in 1980

[5/] Species not captured in 1979

The number of captures of dominant species was generally lower in 1980 than in 1979. The reason for this is unknown but the number of deer mouse captures in 1979 was considered high (RBOSC 1980a). The difference in number of captures is within expected changes due to normal fluctuation in small mammal populations.

Spearman's Rank Correlation Coefficients could not be calculated because of the small number of species captured (Sokal and Rohlf 1969). A high degree of similarity in small mammal populations may exist in similar habitats in the Tract C-a area as evidenced by the low number of separate species captured and the high number of individuals captured of one species in all habitats. Results of the small mammal trapping program will be compared for the same habitats in control and treatment areas between years throughout the remainder of the MDP in an effort to determine if the small mammal population in one area changes in relation to the other area as tract development progresses.

B. Avifauna Studies

1. Objectives and Rationale

The objectives of the avifauna program are to determine the species presence, habitat affinity, relative densities (number observed per hectare of habitat) and relative abundance of avifauna species in sagebrush and pinyon-juniper habitats in control and treatment areas. Appreciable changes over time within the habitats are compared.

2. Methods

The methods for collection and analysis of these data were described in RBOSC MDP Monitoring Report 5 (RBOSC 1980a) and are not repeated herein.

3. Results and Discussions

Densities and relative abundances of all avifauna species observed during June 1979 and 1980 in the pinyon-juniper and sagebrush habitats for the control and treatment areas are presented in Tables 3-30 and 3-31 respectively. All 1980

Table 3-30. Densities[1/] of Avifauna Species Observed in Two Habitat Types in RBOSC Treatment Area 5 and Control Area 6 During June Sampling Periods in 1979 and 1980[2/]

	Pinyon/Juniper Habitat				Sagebrush Habitat			
	Treatment Area 5		Control Area 6		Treatment Area 5		Control Area 6	
	1979	1980	1979	1980	1979	1980	1979	1980
Marsh Hawk		.06					.06	
American Kestrel								.06
Mourning Dove	.11	.11	.07					
Common Nighthawk		.11					.06	
Broad-tailed Hummingbird				.07				.06
Hairy Woodpecker	.06							
Gray Flycatcher			.07					
Scrub Jay				.21				
Black-billed Magpie			.07					
Common Raven	.22		.35	.14	.07	.07	.06	
Piñon Jay			.07	1.89				
Clark's Nutcracker				.21				
Mountain Chickadee	.11	.28	.28	.14				
Plain Titmouse			.14					
White-breasted Nuthatch				.14				
House Wren	.06							
Sage Thrasher					.43	.22		.18
Mountain Bluebird	.34	.40	.14	.07			.12	.30
Blue-gray Gnatcatcher	.11	.28						.12
Solitary Vireo	.11							
Black-throated Gray Warbler	.51	.28	.70	.35				
Brown-headed Cowbird	.40	.06				.29		.06
Western Tanager		.06						
Green-tailed Towhee	.22	.22	.35	.48	.43	.65	2.02	1.01
Rufous-sided Towhee		.11						
Vesper Sparrow								.30
Chipping Sparrow	.56	.22	.63	.70				
Brewer's Sparrow		.34	.42		3.55	2.17	2.96	2.25
Total density of all species per hectare	2.81	2.53	3.29	4.40	4.48	3.40	5.28	4.34
Total number of species observed	12	13	12	11	4	5	6	9

1/Numbers represent number of sightings of each species per hectare

2/Not all species were seen in both years

Table 3-31. Relative Abundances[1/] of Avifauna Species Observed in Two Habitat Types in RBOSC Treatment Area 5 and Control Area 6 During June Sampling Periods in 1979 and 1980[2/]

	Pinyon/Juniper Habitat				Sagebrush Habitat			
	Treatment Area 5		Control Area 6		Treatment Area 5		Control Area 6	
	1979	1980	1979	1980	1979	1980	1979	1980
Marsh Hawk		.02					.01	
American Kestrel								.01
Mourning Dove	.04	.04	.02					
Common Nighthawk		.04					.01	
Broad-tailed Hummingbird				.02				.01
Hairy Woodpecker	.02							
Gray Flycatcher			.02					
Scrub Jay				.05				
Black-billed Magpie			.02					
Common Raven	.08		.11	.03	.01	.02	.01	
Piñon Jay			.02	.43				
Clark's Nutcracker				.05				
Mountain Chickadee	.04	.11	.09	.03				
Plain Titmouse			.04					
White-breasted Nuthatch				.03				
House Wren	.02							
Sage Thrasher					.10	.06		.04
Mountain Bluebird	.12	.16	.04	.02			.02	.07
Blue-gray Gnatcatcher	.04	.11						.03
Solitary Vireo	.04							
Black-throated Gray Warbler	.18	.11	.21	.08				
Brown-headed Cowbird	.14	.02				.09		.01
Western Tanager		.02						
Green-tailed Towhee	.08	.09	.11	.11	.10	.19	.38	.23
Rufous-sided Towhee		.04						
Vesper Sparrow								.07
Chipping Sparrow	.20	.09	.19	.16				
Brewer's Sparrow		.14	.13		.79	.64	.56	.52

1/Numbers represent number of sightings of each species per hectare divided by the total number of sightings of all species per hectare

2/Not all species were seen in both years

avifauna observations are presented in Appendix 3-2.2 by date, transect, habitat and area.

The avifauna data collected in 1980 were very similar to those collected in 1979. In both years more species and higher numbers of birds were observed in the pinyon-juniper habitats than in the sagebrush habitats in both the control and treatment areas. The most frequently observed species in the pinyon-juniper habitats in 1980 were not the ones seen most frequently in 1979, but the number of individuals for the more common species remained similar. For example, the number of individuals in one large flock of piñon jays (Gymnorhinos cyanocephala) in the control pinyon-juniper habitat influenced the results for that area. Commonly observed species in the pinyon-juniper habitats continue to be the black-throated gray warbler (Dendroica nigrescens) and chipping sparrow (Spizella passerina), in both treatment and control areas. Both of these species were observed more often in 1979 than in 1980. The number of species observed in the pinyon-juniper treatment area increased from 12 to 13 in 1980 and the number observed in the control area decreased from 12 to 11.

In the two sagebrush habitat study sites, the most frequently sighted species in 1979 and 1980 were Brewer's sparrow (Spizella breweri) and the green-tailed towhee (Chlorura chlorura). No other species was observed in both areas in both years. The total number of species sighted in the sagebrush habitats increased from four to five species in the treatment area and increased from six to nine in the control area in 1980. Variations in the number of avifauna species sighted and in the number of sightings of any one species within a habitat between years are within the expected differences due to normal fluctuation. None of the density or relative abundance differences for any avifauna species between 1979 and 1980 can be attributed to tract development since avifauna sightings in the control and treatment habitats differed between 1979 and 1980 in a similar way.

C. Mule Deer Density

1. Objectives and Rationale

Mule Deer (Odocoileus hemionus) are the most important game species in Colorado in terms of recreational use and money expended by hunters. The Piceance Creek

Basin is the wintering area of one of the largest migratory mule deer herds. Tract C-a is within the Piceance Creek Basin which for the most part, corresponds to the Colorado Division of Wildlife's (CDOW) Game Management Unit 22.

Moderate to high numbers of mule deer occur on and in the vicinity of Tract C-a during the winter and migration periods. Deer are uncommon around Tract C-a during the summer.

Consideration of the possible effects of Tract C-a development on mule deer is an integral part of RBOSC's Fish and Wildlife Management Plan. The objectives of RBOSC's mule deer monitoring program are to obtain indices of mule deer density in a 9x9 mile (81 sq mi) study area centered on Tract C-a (tract and 3 mile boundary), to compare indices of mule deer density from the study area with those from Game Management Unit 22 and, if possible, to compare differences in mule densities within various portions of the study area.

2. Methods

Mule deer densities can be estimated from pellet group density data as mule deer defecate a reasonably uniform number of times daily (Neff 1968). The number of pellet groups per unit area, days of use by deer and deer per unit area in the RBOSC study area are determined as described by Overton (1971). The methods followed for collection and analysis of these data were described in RBOSC MDP Monitoring Report 1 (RBOSC 1978a) and are not described herein.

3. Results and Discussion

Mule deer pellet groups have been counted every Spring and Fall since 1979. Counts are made in 20 permanent plots in seven 160 acre sample units which lie within the nine blocks (nine sq mi per block) comprising the RBOSC mule deer study area (see Figure 3-1). Deer density estimates, based on pellet group counts, for the MDP monitoring period are presented in Table 3-32. Detailed data on each plot for the 1980 September sampling period are presented in Appendix 3-2.3.

Table 3-32. Estimated Number of Mule Deer per Square Mile by Block of the RBOSC Study Area for Three Winter and Three Summer Periods (September 1977 - September 1980)[1/]

Block	Winter Period[2/]				Summer Period[3/]			
	77-78	78-79	79-80	Average	78	79	80	Average
1	63.0	62.2	32.4	52.5	24.9	19.0	10.7	18.3
2	46.8	72.1	29.7	49.5	28.5	4.7	24.9	19.4
3	63.0	33.4	22.5	39.6	22.5	7.1	17.8	15.8
4	43.2	28.0	27.9	33.0	13.0	7.1	16.6	12.2
5	100.0	72.1	48.6	73.6	17.8	21.4	14.2	17.8
6	64.0	54.1	48.6	55.6	11.9	7.1	3.6	7.5
7	38.7	23.4	10.8	24.3	7.1	11.9	16.6	11.9
8	30.6	25.3	20.7	25.5	7.1	7.1	3.6	5.9
9	9.0	17.1	13.5	13.2	4.7	20.2	2.4	9.1
Averages	50.9	43.1	28.3	40.8	15.3	11.7	12.3	13.1

[1/] Based on pellet group counts with a defecation rate of 13 pellet groups per deer per day

[2/] Based on an average of 165 days in the winter accumulation period

[3/] Based on an average of 120 days in the summer accumulation period

Deer enter the study area in the Fall generally as a result of increasing snow depth or inclement weather which forces them to abandon higher elevation summer ranges. Because of individual tolerances to winter conditions, the deer leave higher elevations, enter the study area and move out of the study area over a variable period of time. Depending on weather conditions, migrating deer begin arriving in the study area in October and the majority of deer reach the study area by December 1. During moderate to severe winters deer may remain at lower elevations throughout the winter.

During mild winters deer often move back and forth along several elevational ranges in response to variations in snow depths. Spring migrations away from the study area are also dependent upon weather conditions but generally occur over a shorter period of time once migration is initiated. The majority of the deer leave the study area by April 1. Few deer remain in the area during Summer.

Because the exact number of days that deer are in the study area is unknown, the deer density indices are computed using an average number of days that deer would be present during an average winter. Pellet counts are made in May, after the majority of deer have left the area, to obtain an index of winter use; and in September, before the majority of deer arrive, to obtain a qualitative index of deer numbers during the Summer. Plots are cleared in September prior to the winter accumulation period.

Comparisons of all pellet group counts for the three years of the MDP monitoring program show significant differences in the main effects listed in Table 3-33. Significant differences in the number of pellet groups counted per plot existed in each of the three years of the study (Table 3-34). The winter of 1977-1978 exhibited near normal snowfall in terms of amount and duration of cover. Deer numbers were fairly high in the Piceance Basin during the winter, and a high number of pellet groups was counted in the RBOSC study area. Deer populations subsequently increased, and a higher number of deer were in the Basin at the beginning of the 1978-79 winter than at the beginning of the 1977-78 winter. The 1978-1979 winter was severe in terms of amount of snowfall and length of time deep snow was on the ground. As a result, a large portion of the deer herd in the area (and throughout the west) died of starvation and

Table 3-33. Summary of Three-Way Mixed Model Analysis of Variance on Main Effects in Variation in RBOSC Mule Deer Pellet Group data,[1/] September 1977 Through September 1980[2/]

Source of Variation	Degrees of Freedom	Type 1 Sum of Squares	F Value	PR>F[3/]
Year	2	13.212*	23.31	0.0001
Season	1	118.584*	418.38	0.0001
Block	8	46.774*	20.63	0.0001
Year x Season	2	10.326*	18.22	0.0001
Season x Block	8	29.320*	12.93	0.0001
Year x Block	16	9.835*	2.17	0.0044
Year x Season x Block	16	13.157*	2.90	0.0001

* Significant at $\alpha = 0.05$

[1/] Class (Main Effect) Level Information

Class	Levels	Values
Year	3	1978, 1979, 1980
Season	2	Winter, Summer
Block	9	1, 2, 3, 4, 5, 6, 7, 8, 9

Number of Observations in Data Set = 7560

[2/] Study plots were established in September 1977. Data were first taken in May 1978 for the preceeding winter period. Pellet group counts are subsequently made in May and September to determine winter and summer deer use respectively. Data presented for a given year included pellet groups counted during the summer of that year and the preceeding winter.

[3/] PR>F represents the significance probability (α) associated with F

Table 3-34. Results of a Duncan's Multiple Range Test for the Significant Main Effect, Year, Differences in Deer Pellet Group Counts Per Plot

Grouping	Mean Pellet Groups Per Plot	N	Year
A	0.25	2520	1978
B	0.21	2520	1979
C	0.15	2520	1980

Means with the same letter are not significantly different.

Alpha Level = .05 Degrees of Freedom = 7506 Mean Square = 0.283

exposure (personal communication, John Gray, CDOW, Grand Junction). This die-off started in the winter and continued into early spring. Fewer pellet groups were counted in May of 1979 than in May of 1978, but the number of groups per plot may not be indicative of the numbers of deer which survived the winter, as groups left by the high deer population in the fall were counted in May. The results of the winter die-off of 1978-79 were evident in the number of pellet groups counted in May of 1980. Significantly fewer deer pellet groups were counted in the RBOSC study area for the winter of 1979-80, a fairly normal winter, than in either of the two previous ones. This indicates that the Piceance Basin deer herd was reduced in numbers as a result of the winter kill. Any effect of tract development on the deer herd is masked by this naturally occurring fluctuation in the population.

Summer deer populations are very low in the RBOSC study area. Significant differences in the number of pellet groups per plot in winter and summer, as presented in Table 3-35, were evident for the three-year MDP study period.

The number of pellet groups counted per plot was significantly different among the nine blocks comprising the RBOSC study area (Table 3-36). For each of the three years of the MDP period to date, Tract C-a, represented by Block 5, has had the highest number of pellet groups of the nine blocks which are counted. This higher deer density also is reflected in deer per square mile (Table 3-32). It is not known why the tract has the highest density of all of the nine blocks in the study area. The diversity of habitats appears greater in Block 5 than in the other blocks, and higher elevation habitats (especially mixed brush) intermingle with lower elevation habitats (pinyon-juniper and bottomland sagebrush) in Block 5. Detailed studies of characteristics of plots with varying numbers of mule deer pellet groups, as presented in Appendix 3-2.4, will continue throughout RBOSC's activity on Tract C-a. This will be done in an effort to understand the impact of tract development on the deer herd and to develop adequate mitigation techniques.

D. Mule Deer Road Kill Survey

The Piceance Creek Basin is the center of a great deal of oil shale and natural gas energy development activity. Increased activity has resulted in increased

Table 3-35. Results of a Duncan's Multiple Range Test for the Significant Main Effect, Season, Differences in Deer Pellet Group Counts Per Plot

Grouping	Mean Pellet Groups Per Plot	N	Season
A	0.32	3780	Winter
B	0.08	3780	Summer

Means with the same letter are not significantly different.

Alpha Level = .05 Degrees of Freedom = 7506 Mean Square = 0.283

Table 3-36. Results of Duncan's Multiple Range Test for the Significant Main Effect, Block, Differences in Deer Pellet Group Counts Per Plot

Grouping	Mean Pellet Groups Per Plot	N	Block
A	0.35	840	5
B	0.26	840	1
B			
B	0.26	840	2
B			
B	0.24	840	6
B			
C B	0.19	840	3
C			
C D	0.17	840	4
D			
E D	0.13	840	7
E			
E	0.12	840	8
E			
E	0.08	840	9

Means with the same letter are not significantly different.

Alpha Level = .05 Degrees of Freedom = 7506 Mean Square = 0.283

traffic flows across mule deer migration routes. The Colorado Division of Wildlife (CDOW) is interested in obtaining data relative to mule deer mortality as a result of deer-vehicle collisions.

1. Objectives

The objective of this program is to provide data on mule deer mortality along County Road 24 from Piceance Creek to Tract C-a for compilation and use by the CDOW.

2. Methods

The methods for collection of these data were described in RBOSC MDP Monitoring Report 5 (RBOSC 1980a) and are not repeated herein.

3. Results and Discussions

Locations of deer killed by collisions with vehicles along County Road 24 from winter 1979-80 through 1980 are shown in Figure 3-3. A total of 13 deer was found dead along the 13 mile length of this road. Fewer deer were seen along the road during this reporting period than were seen during the winter of 1978-79; however, more deer were killed by vehicular traffic in 1979-80. Differences in the traffic volume and deer behavior probably resulted in the increase in deer fatalities. The traffic volume along this road is not measured by RBOSC; however, it is expected to have increased over the two reporting years. The deer behavior differences probably had an equal or larger effect on the number of deer road kills. During the winter of 1978-79, deer were undernourished and were subsequently very lethargic. Apparently deer were less active and were not as likely to be crossing roads during periods of heavy traffic. Because of their weakened condition, the deer may have moved more slowly, thus providing drivers an opportunity to see and avoid them. When deer are in good physical shape, such as 1979-1980, they are more apt to dart suddenly across the road and become a victim of a vehicle collision.

Signs warning drivers of deer crossings have been placed on each side of sections of County Road 24 where deer/vehicle collisions occur most frequently.

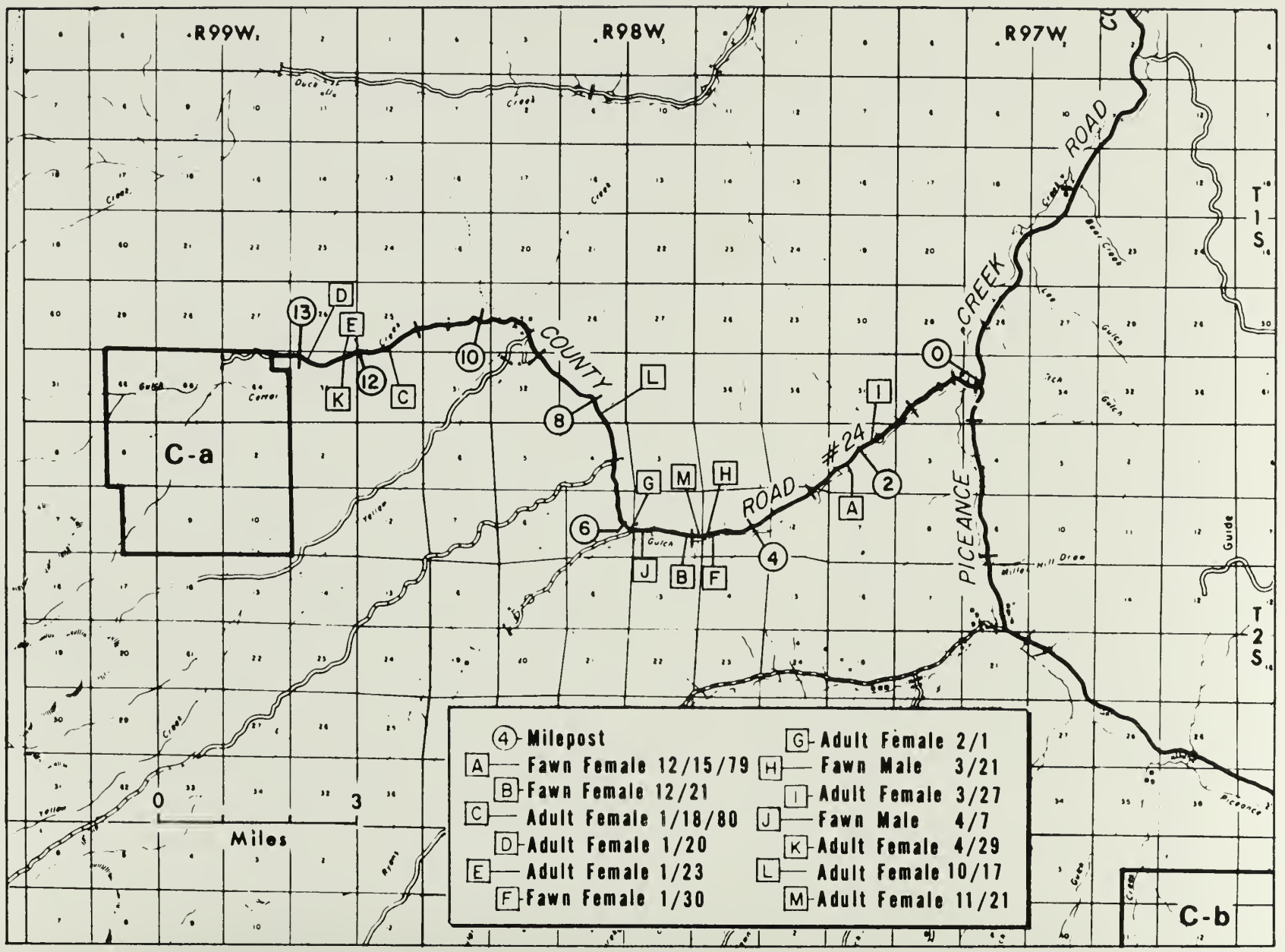


Figure 3-3. Locations of Mule Deer Carcasses Found Along County Road 24 During the Study Period.

E. Feral Horse Abundance

1. Objectives and Rationale

Feral horses occur on and in the vicinity of Tract C-a. These horses are protected under federal law and are under the jurisdiction of the BLM. Feral horses compete with cattle and, to a lesser extent, with mule deer for available forage. The objective of feral horse monitoring studies is to provide qualitative information concerning the status of feral horses in the RBOSC study area (note: the feral horse study area is the same as the mule deer study area).

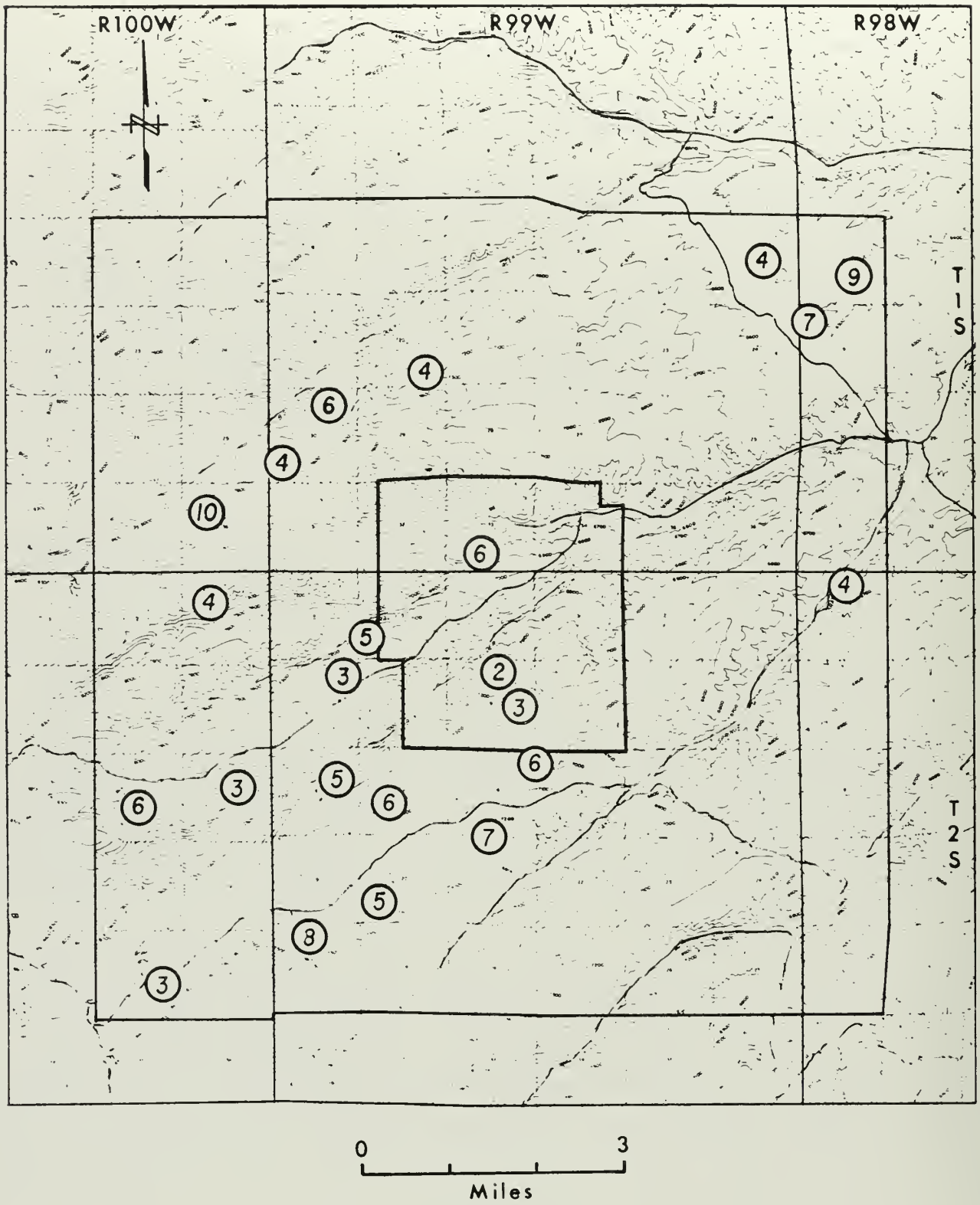
2. Methods

The methods followed for collection of data on feral horses were described in RBOSC MDP Monitoring Report 1 (RBOSC 1978a) and are not repeated herein.

3. Results and Discussions

Feral horses on the Tract C-a study area were counted from a helicopter in January 1980. Twenty-four bands of horses totaling 120 individuals were observed in the study area (Figure 3-4). Ninety-nine horses in 21 bands were observed during the January 1979 count. Weather conditions were good for horse observation during both years and the majority of horses in the study area was probably counted.

During baseline studies, a total of 135 feral horses was estimated in two large BLM grazing allotments which included part of the RBOSC MDP study area. No feral horses had been removed from the region by the BLM during the period from baseline to the 1980 aerial count. The density observed in the study area during 1980 is probably higher than that estimated during baseline.



(2) Number of horses in band and approximate location of band

Figure 3-4. Feral Horses Observed During the January 1980 Aerial Census

Foal success in the study area was estimated by counting horses according to age group during June 1980. Age ratios for observed horses are presented below:

Age Class	No. Observed	% of Total Observed
Adult and Yearling	52	74.3
Foal	18	25.7

Because feral horses foal over a long time period in the summer, some of the horses may have been counted in the wrong age class and some mares may not have foaled at the time of the count. The BLM anticipates a 15 to 20 percent increase in the feral horse population annually. The higher foal proportion for 1980 probably was a result of the moderate winter of 1979-80. The total increase in the feral horse population for the year is not known but may have been in the range of 15 to 20 percent. In August and September 1980, the BLM removed a substantial number of horses from the study area. The effects of this removal may be evident in the 1981 feral horse count.

F. Threatened, Endangered, and Protected Species

Baseline, interim and MDP studies indicate that Tract C-a does not provide critical habitat for any state or federally protected endangered species. The only species in these categories seen in the tract area is the bald eagle. This species is occasionally seen foraging in the tract vicinity and feeding on road kills during winter months.

Golden eagles and other raptor species that are protected in Colorado were seen during the reporting period. A pair of golden eagles nested at milepost 2 along County Road 24. The one chick in that nest died when it was apparently chilled by a sudden rainstorm in May.

3.3 SUMMARY

The components of the Terrestrial Monitoring Program examined during the December 1979 through November 1980 reporting period include vegetation type mapping and stress, phytosociological, range production and utilization, browse utilization and condition, small mammal, avifauna, mule deer and feral horse studies.

Color infrared photographs taken during 1980 showed only minor variations from data collected during 1979. Apparent decreases in moisture were noted in portions of Box Elder Gulch and to the north of Dry Fork of Corral Gulch. Apparent increases in moisture were noted on portions of Sagebrush Ridge and to the northeast of the MIS Area. These differences seem to be due in part to variations in processing and/or photographic printing between the two years. Increased herbaceous vegetation on some revegetated areas also was evident. Data seem to indicate that dewatering and subsequent reinjection and/or discharge of water on Tract C-a during the reporting period have not altered, to any large degree, the vegetational communities which were present on tract during the 1979 sampling period.

Phytosociological studies were conducted on 10 transects (5 control, 5 treatment) within the upland sagebrush vegetation type on and adjacent to Tract C-a. Coverage of trees and shrubs averaged 23.6 percent in the control area and 31.6 percent in the treatment area. Sagebrush (Artemisia tridentata) was the dominant shrub on both areas. Density of sagebrush averaged 6060 stems per hectare on the control area and 7190 stems per hectare on the treatment area. Coverage of pinyon pine (Pinus edulis) and juniper (Juniperus osteosperma) was low on both the control and treatment areas. Coverage of herbaceous species was 44.8 percent on the control area and 32.4 percent on the treatment area. Bluegrass (Poa spp) and wheatgrass (Agropyron spp) species were the dominant grasses on both areas. The prominent forbs on the control area were the northern sweetvetch (Hedysarum boreale) and lupine (Lupinus argenteus). The most prominent forb species on the treatment area was Hoods phlox (Phlox hoodii). Statistical comparisons of arcsine transformed coverage estimates for forbs, grasses, shrubs and trees (lumped by growth form) between control and treatment

areas, as well as among transects within each location, showed no significant differences ($\alpha = 0.05$).

Range productivity and utilization studies indicated that production ranged from 73 kg/ha in the pinyon-juniper to 291 kg/ha in the mixed brush vegetation type. Production of grasses exceeded that for forbs in the three vegetation types sampled. Wheatgrass (Agropyron spp), Indian ricegrass (Oryzopsis hymenoides), and bluegrass (Poa spp) were the dominant grasses in all three vegetation types. Composition of forbs among the three vegetation types was variable. Bastard toadflax (Comandra umbellata), false buckwheat (Eriogonum spp), northern sweetvetch (Hedysarum boreale) and lupine (Lupinus argenteus) were dominant in the mixed brush type. Arrowleaf balsam root (Balsamorhiza sagittata) and goldenweed (Haplopappus nuttallii) were the most common forbs in the pinyon-juniper type. The upland sagebrush type had dominant forbs found in both the mixed brush and pinyon-juniper types. These species included milk-vetch (Astragalus spp), Comandra umbellata, Haplopappus nuttallii, and Lupinus spp.

Statistical comparisons of range production among transects within respective vegetation types for 1980 indicated that there were significant differences ($\alpha = 0.05$) in grass production for all three types. Forb production was significantly different within the mixed brush and pinyon-juniper types. Comparisons among years (1978, 1979, 1980) by vegetation type indicated that grass production was significantly higher for 1979 and 1980 than for 1978 within all three vegetation types. No significant differences were noted in forb production within any of the vegetation types sampled during the same period.

Forage utilization among the three vegetation types was variable. Within the mixed brush type utilization was relatively constant over three years, ranging from 29 percent in 1979 to 31 percent in 1980. Utilization within the upland sagebrush type increased from 36 percent in 1978 to 40 percent in 1980. A marked decrease in utilization was evidenced within the pinyon-juniper vegetation type, from 48 percent in 1978 to 10 percent in 1980.

Browse studies indicated that the weighted average percent utilization ranged from 1 percent in the upland sagebrush to 10 percent in the pinyon-juniper vegetation type. Utilization in all vegetation types decreased relative to 1979 data and is the lowest recorded in five years of study. Results of statistical analyses using arcsine transformed estimates of leader utilization among years (1978, 1979, 1980) by individual browse species indicate significant differences ($\alpha = 0.05$) in use of serviceberry (Amelanchier utahensis) and mountain mahogany (Cercocarpus montanus) within the mixed brush type; sagebrush (Artemisia tridentata), pinyon pine, bitterbrush (Purshia tridentata), and mountain mahogany within the pinyon-juniper type; and sagebrush within the upland sagebrush vegetation type. All of these species except for mountain mahogany in the mixed brush type had significantly lower leader use during 1980 than during 1978. Variations in utilization between 1980 and 1979 generally were not significant. Lower use in 1980 relative to 1978 may be due to decreases in the mule deer herd size between the two years. The smaller mule deer population combined with the relatively harsh 1978-79 winter season have resulted in the continued decline in browse use since May 1978.

Range condition ratings based on age class and/or hedging class were similar to those evidenced during 1979; however, there is some indication that range condition is improving. Improvements are evident primarily in ratings based on hedging classification, and are probably due to lower browse utilization. Because the RBOSC browse studies are designed to census the same individuals on a yearly basis, one would not expect to find large changes in range condition ratings based on either hedging or on age classification.

The small mammal species most frequently captured during this monitoring period were the deer mouse (Peromyscus maniculatus) and the least chipmunk (Eutamias minimus). These same species also were captured most frequently during baseline studies and in 1979 MDP studies. No change which could be attributed to tract development could be detected in the small mammal population within the study area.

More species and a higher number of birds were seen in the pinyon-juniper habitats than in the sagebrush habitats in both 1979 and 1980. The pinyon-juniper habitat has a more heterogeneous vegetative community structure than

the sagebrush habitat and can support a more diverse avifauna population. Commonly observed bird species in the pinyon juniper habitats were the black-throated gray warbler (Dendrocia nigrescens) and the chipping sparrow (Spizella passerina). Commonly observed species in the sagebrush habitats were the Brewer's sparrow (Spizella breweri) and the green-tailed towhee (Chlorura chlorura). Differences in numbers of birds observed between years are within expected normal fluctuations in densities.

Mule deer (Odocoileus hemionus) density, estimated from pellet group counts in the RBOSC study area, has declined from 51 deer per square mile in 1978 to 28 deer per square mile in 1980. This decline is probably a result of the severe winter kill of 1978-79. Effects of this winter kill will probably be evident in the density estimates for several years. The estimated deer density has been highest in the tract development portion of the study area for each of the three years of the MDP. Explanations for this high density are uncertain. Continued study will further the knowledge of the factors influencing mule deer use of one area in preference to another, and this information will then aid in planning reclamation and mitigation efforts on and adjacent to Tract C-a.

Thirteen deer killed by collisions with vehicles were found along Rio Blanco County Road 24 during the reporting period. Signs warning drivers of deer road crossing areas were erected along this road in an effort to reduce this loss.

Twenty four bands of feral horses totaling 120 individuals were counted in the RBOSC study area in January 1980. Ninety-nine horses in 21 bands were counted in 1979. A moderate winter and good foal success probably account for this increase. The removal of horses from the area by the BLM may cause a reduction in the number of horses counted in subsequent surveys.

The Tract C-a area does not provide critical habitat for any endangered wildlife. Bald eagles are commonly seen foraging in the area during moderate to severe winters. This species ranges over a large part of western Colorado during the winter months. Protected species, such as the golden eagle and the raven, are commonly seen in the area throughout the year.

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SECTION 4
AQUATIC STUDIES

The MDP Aquatic Monitoring Program is designed to provide information appropriate to identifying and measuring the potential effects of modular development on aquatic biota in the vicinity of Tract C-a. The program was devised following a complete evaluation of data obtained during the RBOSC baseline studies and a determination of the possible impacts of project activities. Criteria for selecting the aquatic parameters to be measured included ecological importance, sensitivity to environmental change, and ease of sampling. Table 4-1 lists the sampling frequency and the parameters measured at each location.

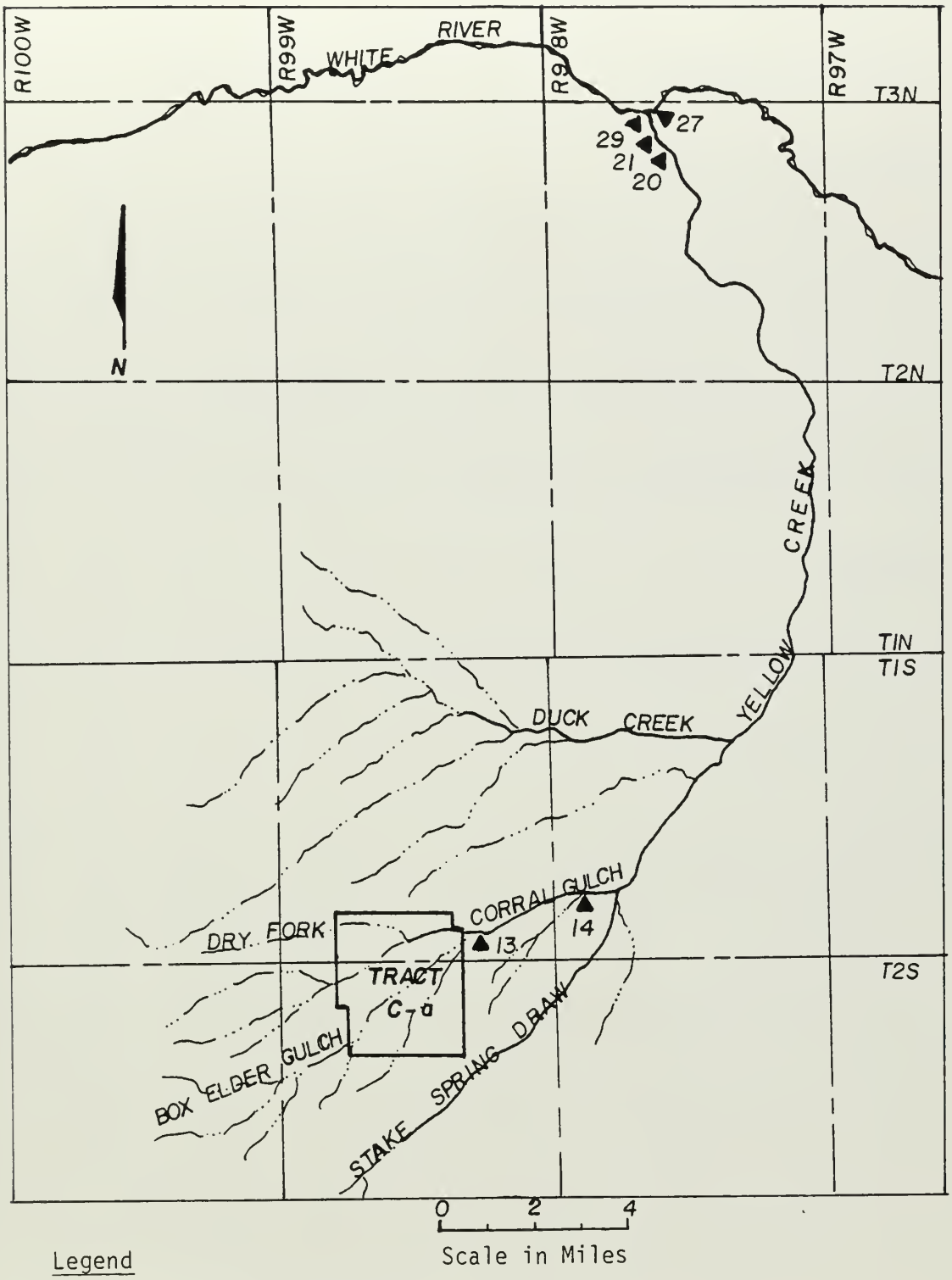
Six sampling sites are used in the MDP monitoring program (Figure 4-1):

- Station 13 (springbrook habitat) at the USGS gaging station in Corral Gulch (east)
- Station 14 (pond habitat) in Corral Gulch (east)
- Station 20 (springbrook habitat) at the USGS gaging station on Yellow Creek
- Station 21 (springbrook habitat) on Yellow Creek below the USGS gaging station
- Station 27 (White River back channel habitat) above the confluence of Yellow Creek with the White River
- Station 29 (White River back channel habitat) below the confluence of Yellow Creek with the White River

MDP sampling was initiated in October 1977. This report provides the results of the 1980 MDP aquatic studies. Comparisons of these results to data collected during baseline studies (1974-1976) have also been included.

Table 4-1. Aquatic Studies Monitoring Schedule

Parameter	Location	Frequency
ABIOTIC COMPONENTS		
Physical Measurements		
Stream Velocity Turbidity Dissolved Oxygen pH Specific Conductance Depth Width Stream Substrate	All Stations	6 times/year (April, May, June, July, August, October)
Water Quality Measurements (White River)		
Boron Calcium Chloride Fluoride Magnesium Nitrate Orthophosphate Potassium Total Phosphate Silica Sulfate Sodium Alkalinity Total Dissolved Solids Bicarbonate	Stations 27, 29 (See Figure 4-1)	6 times/year (April, May, June, July, August, October)
BIOTIC COMPONENTS		
Periphyton		
Species Composition Relative Abundance Biomass Diversity	All Stations	6 times/year (April, May, June, July, August, October)
Benthos		
Species Composition Relative Abundance Diversity	All Stations	6 times/year (April, May, June, July, August, October)



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▲ Aquatic Baseline Study Sampling Locations

Figure 4-1. Locations of Aquatic Sampling Sites, Tract C-a

4.1 ABIOTIC COMPONENTS

A. Physical Measurements

1. Objectives and Rationale

The physical measurements program is designed to monitor selected physical parameters at MDP aquatic sampling stations and relate these data to water quality and aquatic biota conditions. The parameters selected for monitoring are those which may be affected by project activities and which may influence the distribution, abundance, and composition of aquatic biota in the study area. Chemical parameters, such as dissolved oxygen, which were recorded in conjunction with the physical measurements are also presented in this section.

2. Methods

Methods used to collect physical stream data were described in RBOSC MDP Monitoring Report 1 and are not repeated herein.

3. Results and Discussion

A comparison of the measurements of physical parameters obtained during the 1980 MDP studies with the results from previous years is presented in Tables 4-2 through 4-7. These data indicate much seasonal, as well as year-to-year variability. With a few exceptions, no consistent trends or permanent changes are apparent in the parameters at each station. An increase in the flow volume occurred at Stations 13 and 14 (Figure 4-1) during 1979 and 1980 due to operational water discharge into Corral Gulch. As a result, increased stream width, depth and velocity were evident at both stations during these years. Increase in turbidity at Station 13 also could have been related to the effects of water discharge. No substantial differences are noted between baseline and MDP physical parameter measurements for stations on Yellow Creek (20 and 21) and the White River (27 and 29).

Table 4-2. Physical and Chemical Characteristics at Station 13 for RBOSC MDP Studies (1977-1980) and RBOSC Baseline Studies (1974-1976)

	PARAMETERS									
Date	Water Temp. (°C)	Conductivity (µmhos/cm)	Diss. Oxygen (mg/l)	Total Alkalinity (mg/l)	pH	Turbidity (JTU)	Substrate[1/]	Width (m)	Depth (cm)	Velocity (mps)
Baseline										
10-11/74	10	1,200	8.9	410	7.8	2	Sa,Gr	0.91	2.5,2.5,3.8	0.15
4/75	9	1,730	5.2	716	8.3	>1,000	Gr,Sl	0.91	7.6	0.30
5-6/75	20	1,500	5.6	646	8.3	450	Gr,Sa,Sl	1.3	10.2	0.52
7-8/75	18	1,200	6.2	396	7.5	6	Gr,Sa	0.85	7.6	0.61
8-9/75	11	1,300	7.6	419	7.6	1	Gr,Sa	0.76	10.2	0.34
10/75	13	1,200	8.4	421	7.8	1	Gr,Sa	0.61	7.6	0.58
4/76	13	1,150	7.8	435	7.5	>1	Gr,Sa	1.2	10.2	0.43
5-6/76	18	1,100	6.1	379	7.8	163	Gr,Sa	0.76	12.7	0.64
7-8/76	15	1,200	7.1	381	8.0	4	Gr,Sa	0.91	7.6	0.64
8-9/76	15	1,100	7.0	397	7.9	12	Gr,Sa	0.91	5.1	0.43
MDP										
10/77	19	1,200	8.0	401	7.8	..	Gr	1.1	5.1	0.21
4/78	17	1,500	5.1	584	8.3	60.0	Gr	1.1	15.2	0.61
6/78	13	1,500	6.4	410	7.8	520.0	Gr,Sa	0.91	15.2	0.88
7/78	15	1,400	6.6	302	8.1	..	Gr,Sa	1.5	15.2	0.70
8/78	12	1,600	7.4	482	8.0	8.8	Gr	1.2	10.2	0.52
10/78	11	1,800	7.9	496	7.8	1.5	Gr	1.4	17.8	0.61
4/79	15	1,050	6.3	450	7.8	155	Gr	1.46	22.7	0.76
5/79	13	955	6.9	423	7.9	420	Gr	1.92	17.8	0.98
6/79	15	1,375	5.3	454	10.2	44	Gr	2.23	10.2	0.58
7/79	15	1,225	12.3	447	8.3	..	Gr,Sa	2.29	10.2	0.37
8/79	17	1,413	4.7	482	7.9	32	Gr,Sa	1.83	10.2	0.64
10/79	17	1,325	7.2	413	8.1	12	Gr,Sl	1.46	10.2	0.58
4/80	13	1,390	7.5	495	6.4	0.7	Gr,Sa,Sl	1.55	6.9	0.44
5/80	11	1,100	7.7	377	7.9	420	Gr,Co,Sl	2.79	12.2	1.2
6/80	10	1,230	7.4	427	7.6	46	Gr,Co,Sl	2.0	10.4	0.65
7/80	16	1,305	7.8	465	7.6	..	Gr,Sa,Co	1.6	9.1	0.68
8/80	12	1,400	7.0	525	7.6	2.0	Gr,Sa,Co,Sl	1.6	8.5	0.44
10/80	10	1,500	9.8	520	7.6	0.8	Gr,Sa,Co	0.97	9.8	0.33

[1/] Substrate abbreviations: Gr = Gravel; Sa = Sand; De = Detritus; Co = Cobble; Sl = Silt

Table 4-3. Physical and Chemical Characteristics at Station 14 for RBOSC MDP Studies (1977-1980) and RBOSC Baseline Studies (1974-1976)

Date	PARAMETERS									
	Water Temp. (°C)	Conductivity (µmhos/cm)	Diss. Oxygen (mg/l)	Total Alkalinity (mg/l)	pH	Turbidity (JTU)	Substrate[1/]	Width (m)	Depth (cm)	Velocity (mps)
Baseline										
10-11/74	8	1,800	13.4	454	8.2	1	Cl	0.30	15.2	0.40
4/75	5	1,800	11.1	492	8.4	9	Si	0.60	5.1	0.15
5-6/75	18	1,550	12.6	485	8.2	2	Sa,Cl	0.76	7.6-15.2	0.00
7-8/75	19	2,000	12.9	532	7.9	7	Sa,Si	1.10	7.6-15.2	0.00
8-9/75	12	1,850	7.4	564	7.9	2	Si	0.73	10.2	0.30
10/75	14	1,800	14.4	520	8.3	4	Si	0.91	15.2	0.12
4/76	9	1,750	9.7	546	7.9	3	Sa	0.46	10.2	0.37
5-6/76	24	1,750	12.3	510	8.2	2	Gr,Sa	0.46	15.2	0.34
7-8/76	23	1,700	8.5	528	8.0	14	Sa	0.60	7.6	0.46
8-9/76	17	1,200	8.5	542	8.1	>1	Sa	0.60	5.1	0.46
MDP										
10/77	8	1,700	9.8	521	7.7	..	Sa,De	0.60	5.1	0.21
4/78	16	1,400	10.1	424	8.4	25.0	Sa,Si,De	0.15	15.2	0.30
6/78	16	1,600	8.6	..	8.4	..	Sa	0.91	22.3	0.58
7/78	14	1,700	9.4	530	8.1	..	Gr,Si	0.61	15.2	0.40
8/78	11	1,800	10.1	495	8.2	1.3	Sa,Si	0.91	30.5	0.18
10/78	6	1,850	9.0	510	7.6	1.0	Si,Gr	1.4	22.3	0.40
4/79	12	2,000	8.5	600	7.0	1.0	Sa,Si	2.6	20.3	0.30
5/79	9	1,500	7.6	529	7.4	2.8	Sa	2.7	12.7	0.15
6/79	11	2,150	8.7	749	8.4	0.8	Gr	2.3	38.1	0.12
7/79	9	2,200	7.7	515	7.2	..	Si,Gr	1.7	15.2	0.27
8/79	10	2,463	6.7	527	7.5	13.5	Si,Sa,Gr	1.6	22.9	0.24
10/79	11	2,175	7.5	520	7.6	3.0	Si,Gr	1.9	27.9	0.09
4/80	15	1,840	9.3	539	7.6	1.0	Gr,Sa,Si	0.94	5.6	0.36
5/80	13	1,795	9.1	512	7.3	15	Gr,Sa,Si	1.4	15.2	0.68
6/80	11	2,037	9.2	555	7.5	0.7	Gr,Si	1.2	24.4	0.27
7/80	15	1,925	9.2	565	7.6	..	Gr,Sa,Si	1.1	19.8	0.39
8/80	10	2,000	9.1	575	7.5	24	Gr,Sa,Si	0.97	29.0	0.42
10/80	9	1,905	12.2	585	7.8	7.5	Sa,Si	0.43	430.0	0.23

[1/] Substrate abbreviations: Gr = Gravel; Sa = Sand; De = Detritus; Co = Cobble; Si = Silt

Table 4-4. Physical and Chemical Characteristics at Station 20 for RBOSC MOP Studies (1977-1980) and RBOSC Baseline Studies (1974-1976)

	PARAMETERS									
Date	Water Temp. (°C)	Conductivity (µmhos/cm)	Diss. Oxygen (mg/l)	Total Alkalinity (mg/l)	pH	Turbidity (JTU)	Substrate[1/]	Width (m)	Depth (cm)	Velocity (mps)
Baseline										
10-11/74	7	3,000	8.7	1,149	8.5	12	Gr	0.70	11.4	0.52
4/75	14	3,700	9.4	1,291	8.6	81	Gr,Sl,Sa	0.30	8.9	0.40
5-6/75	23	3,600	8.2	1,393	8.3	7	Gr,Sa	0.24	10.2	0.43
7-8/75	19	3,800	8.7	1,375	8.8	7	Sa,Sl	0.91-1.8	91.4	0.43
8-9/75	25	3,300	7.2	1,650	8.7	28	Sl,Gr,Sa	1.6	7.6	0.21
10/75	11	3,850	10.6	1,485	8.7	13	Gr,Sa	1.0	7.6	0.40
4/76	19	4,000	9.4	1,632	8.7	110	Gr	1.5	10.2	0.34
5-6/76	22	4,200	6.3	1,740	8.0	12	Gr,Sa	0.91	12.7	0.55
7-8/76	31	4,500	8.6	1,664	8.0	3	Gr,Sa	0.24	7.6	0.34
8-9/76	11	4,000	7.4	1,456	8.7	58	Gr	1.8	7.6	0.37
MOP										
10/77	11	4,100	7.1	1,658	8.6	..	Gr,Sa	0.55	1.8	0.58
4/78	16	4,200	8.2	1,444	8.1	75	Co,Gr	0.91	10.2	0.46
6/78	25	4,800	6.5	..	8.8	..	Gr,Sa	0.61	12.7	0.40
7/78	23	5,000	7.4	2,700	8.9	..	Gr,Sa	0.30	12.7	0.43
8/78	24	4,600	7.4	2,286	9.2	5	Gr,Sl	0.61	7.6	0.21
10/78	11	5,000	7.4	1,732	8.6	2	Gr,Sl	1.7	8.9	0.27
4/79	22	2,500	8.7	1,544	8.3	120.0	Gr,Sa	2.0	12.7	0.40
5/79	24	4,030	7.1	1,620	8.1	66.0	Gr	1.6	15.2	0.64
6/79	21	4,100	6.7	1,616	9.7	4.4	Gr	1.9	15.2	0.43
7/79	18	3,650	5.8	1,476	8.7	2.0	Gr	2.0	10.2	0.46
8/79	21	3,625	7.4	1,370	8.0	16.0	Gr,Sl	3.3	7.6	0.18
10/79	8	3,050	9.0	1,140	8.2	15.0	Gr,Sl	2.8	10.2	0.37
4/80	8	3,445	10.0	1,355	8.5	78.5	Sa,Co,Sl	3.1	6.9	0.25
5/80	22	3,450	8.0	1,305	8.6	53	Sa,Co	3.2	7.6	0.55
6/80	26	3,412	11.0	1,350	8.7	17	Gr,Sa,Co	2.1	11.6	0.39
7/80	27	3,075	10.7	1,130	8.7	..	Sa,Co,Sl	1.9	7.6	0.48
8/80	21	2,825	11.3	1,170	8.6	8.0	Gr,Sa,Co	1.7	9.1	0.73
10/80	12	3,050	13.0	1,190	8.8	640	Sa,Co,Sl	1.5	11.6	0.57

[1/] Substrate abbreviations: Gr = Gravel; Sa = Sand; De = Detritus; Co = Cobble; Sl = Silt

Table 4-5. Physical and Chemical Characteristics at Station 21 for RBOSC MDP Studies (1977-1980) and RBOSC Baseline Studies (1974-1976)

Date	PARAMETERS									
	Water Temp. (°C)	Conductivity (µmhos/cm)	Diss. Oxygen (mg/l)	Total Alkalinity (mg/l)	pH	Turbidity (JTU)	Substrate[1/]	Width (m)	Depth (cm)	Velocity (mps)
Baseline										
10-11/74	8	3,000	9.9	1,244	8.6	2	Sa,Gr	0.91	2.5	0.30
4/75	14	3,700	8.9	1,306	8.6	68	Gr,Si	1.6	10.2	0.46
5-6/75	18	3,400	9.2	1,449	8.3	3	Gr,Sa	1.5	10.2	0.70
7-8/75	19	3,900	8.1	1,451	8.7	8	Gr,Sa	1.4	7.6	0.24
8-9/75	24	3,900	8.8	1,651	8.7	25	Gr,Sa	0.82	10.2	0.37
10/75	8	3,880	10.7	1,567	8.7	20	Gr,Sa	1.0	7.6	0.61
4/76	18	3,900	10.2	1,658	8.7	100	Gr	1.8	10.2	0.27
5-6/76	17	3,900	7.4	1,660	8.5	14	Gr,Sa	3.7	15.2	0.21
7-8/76	28	4,000	10.2	1,558	8.0	14	Gr,Si	1.8	10.2	0.18
8-9/76	11	4,000	7.6	1,600	8.7	176	Gr,Sa,Si	0.30	12.7	0.21
MDP										
10/77	12	4,100	7.9	1,650	8.8	..	Gr	0.91	7.6	0.30
4/78	13	4,200	6.9	1,532	8.7	75.0	Gr,Sa	1.2	10.2	0.30
6/78	20	4,900	6.7	..	8.9	..	Gr,Sa	1.1	15.2	0.52
7/78	23	4,800	7.5	1,404	9.0	..	Gr,Sa	1.2	10.2	0.27
8/78	22	3,800	5.9	2,190	9.0	10.0	Sa,Si	1.2	15.2	0.30
10/78	11	5,000	7.2	2,058	8.6	1.5	Gr	1.4	5.1	0.37
4/79	21	3,220	8.6	1,554	8.4	145.0	Gr,Sa	2.8	7.6	0.52
5/79	28	4,350	5.2	1,590	8.3	75.0	Gr	1.9	10.2	0.43
6/79	21	4,300	6.8	1,662	9.5	6.4	Gr	2.2	10.2	0.52
7/79	22	3,650	6.6	1,490	8.6	1.0	Gr	2.3	7.6	0.43
8/79	24	3,587	7.4	1,298	8.2	14.5	Gr,Si	2.5	10.2	0.24
10/79	13	2,908	8.2	1,060	7.8	17.0	Gr,Si	1.6	10.2	0.52
4/80	9	3,540	9.7	1,318	8.6	87.5	Sa,Co,Si	2.2	8.8	0.62
5/80	23	3,520	7.4	1,315	8.6	49	Sa,Co,Si	2.1	9.1	0.56
6/80	28	3,250	10.9	1,390	8.7	4.1	Gr,Co,Si	1.7	9.8	0.60
7/80	29	3,170	11.0	1,230	8.7	..	Gr,Sa,Co,Si	1.3	10.7	0.68
8/80	24	2,650	10.9	1,135	8.6	10.0	Gr,Co,Si	1.3	18.3	0.65
10/80	13	2,910	12.8	1,410	8.8	450	Gr,Co,Si	1.6	18.0	0.68

[1/] Substrate abbreviations: Gr = Gravel; Sa = Sand; De = Detritus; Co = Cobble; Si = Silt

Table 4-6. Physical and Chemical Characteristics at Station 27 for ROSC MDP Studies (1977-1980) and ROSC Baseline Studies (1974-1976)

Date	Water Temp. (°C)	Conductivity (µmhos/cm)	Diss. Oxygen (mg/l)	Total Alkalinity (mg/l)	pH	Turbidity (JTU)	Substrate[1]	Width (m)	Depth[2] (cm)	Velocity[2] (mps)
Baseline										
10-11/74	11	600,600,700	12.1	199	8.6	7	Co	13.7	5.1,48.3,35.6	0.12,0.12,0.18
4/75	15	850	9.8	207	8.5	44	Gr,Si	14.2	5.1,58.4,10.2	0.12, ..,0.37
5-6/75	12	350	8.9	109	8.0	64	Co	..	91.4	0.49, ..,0.37
7-8/75	18	625,625,625	8.5	473	8.2	28	Sa,Si	13.7	20.3,71.1,45.7	0.12, ..,0.37
8-9/75	18	825,800,800	10.9	206	8.6	10	Co,Sa	13.7	50.8,30.5,17.8	0.03, ..,0.27
10/75	9	775,700,700	11.1	186	8.3	9	Co,Gr	15.2	25.4,55.9,55.9	0.06, ..,0.30
4/76	17	650,640,650	10.6	188	8.4	32	Co	15.5	10.2,55.9,20.3	0.37,0.30,0.21
5-6/76	18	550,550,550	8.0	157	8.0	13	Co	17.1	20.3,66.0,15.2	0.09,0.43,0.21
7-8/76	20	950,925,925	7.3	256	8.0	250	Co,Si	14.0	55.9,55.9,45.7	0.21,0.24,0.12
8-9/76	20	900,900,900	9.7	217	8.4	4	Co,Gr	14.2	40.6,40.6,2.5	0.27, .., ..
MDP										
10/77	9	900,900,900	9.6	214	8.3	59.0	Co	11.9	2.5,25.4	0.24,0.34, ..
4/78	9	700,700,700	9.6	184	8.2	89.0	Co,Si	15.5	20.3,25.4,10.2	0.37,0.58,0.43
6/78	12	550	8.2	136	8.2	54.0	..	..	..	..
7/78	21	670,670,670	7.9	180	8.7	6.0	Co,Si	18.3	20.3,25.4,20.3	0.64,0.76,0.52
8/78	19	700,700,700	10.2	180	8.7	1.0	Co	12.2	15.4,25.4,15.4	0.58,0.64,0.64
10/78	7	800	10.3	178	8.0	0.9	Co,Si	15.8	15.4,35.6,10.2	..,0.43, ..
4/79	12	600,600,600	9.3	182	7.5	97.5	Gr	16.6	35.6,38.1,45.7	0.58,0.61,0.30
5/79	12	450	8.1	130	8.0	150.0	Gr	..	..	..
6/79	10	350	8.7	145	8.2	50.0	..	..	..	..
7/79	20	450	7.7	162	8.4	18.0	Gr	16.5	66,27.9,22.9	0.64,0.64,0.34
8/79	18	813	7.1	227	8.2	9.0	Gr,Sa	14.8	15.2,30.5,35.6	0.40,0.70,0.70
10/79	9	725	8.2	180	7.9	14.0	Sa,Si,Gr	15.5	25.4,43.2,71.1	0.15,0.12,0.49
4/80	11	620	8.0	160	8.2	575	Co,Si	17.1	30.5,45.7,22.9	1.2,1.1,0.7
5/80	12	540	9.2	153	7.8	160	Co,Si	..	..	..
6/80	14	290	9.7	124	7.7	34	..	..	..	..
7/80	20	710	8.8	240	8.3	9.8	Co,Si	13.9	30.5,24.4,17.4	0.52,0.46,0.41
8/80	21	625	10.7	235	8.2	25.5	Gr,Co,Si	11.7	27.4,33.5,18.3	0.66,0.74,0.48
10/80	8	695	10.3	205	7.8	..	Sa,Co,Si	14.3	50.6,51.2,20.7	0.65,0.66,0.43

PARAMETERS

[1] Substrate abbreviations: Gr = Gravel; Sa = Sand; De = Detritus; Co = Cobble; Si = Silt

[2] When water conditions permitted, three measurements were taken at the left, center, and right portions of the river (facing upstream)

Table 4-7. Physical and Chemical Characteristics at Station 29 for R80SC MDP Studies (1977-1980) and R80SC Baseline Studies (1974-1976)

Date	PARAMETERS Water Temp. (°C)	Conductivity (µmhos/cm)	Diss. Oxygen (mg/l)	Total Alkalinity (mg/l)	pH	Turbidity (JTU)	Substrate[1/]	Width (m)	Depth[2/] (cm)	Velocity[2/] (mps)
Baseline										
10-11/74	11	855,750,690	10.8	224	8.7	8	Co,Si	6.9	2.5,30.5,5.1	1.0, ..,0.70
4/75	13	850	10.1	207	8.4	53	Gr,Oe	6.3	2.5,27.9,2.5	0.58, ..,1.1
5-6/75	12	400	8.9	123	8.0	48	Co	..	50.8, ..,50.8	1.8, ..,0.94
7-8/75	18	750,675,625	8.2	453	8.2	20	Co,Gr	10.7	17.8,40.6,15.2	0.64, ..,0.94
8-9/75	18	825,900,875	10.2	230	8.6	15	Co,Sa	13.7	17.8,30.5,17.8	0.70, ..,0.76
10/75	9	875,760,710	10.9	192	8.3	9	Co,Gr	7.9	22.9,33.0,20.3	1.4,1.4,0.55
4/76	11	730,800,1150	10.5	186	8.4	43	Gr,Sa	7.6	10.2,30.5,5.1	0.85,1.2,0.58
5-6/76	19	675,525,500	8.1	175	8.1	14	Co	10.1	7.6,40.6,33.6	0.64,0.94,1.1
7-8/76	20	1050,1000,900	7.4	278	8.0	365	Co	7.3	20.3,27.9,12.7	0.37,0.98,0.76
8-9/76	20	1000,950,900	9.6	240	8.4	20	Co	9.0	20.3,20.3,7.6	1.0, .., ..
MDP										
10/77	9	900,1050,1200	9.7	269	8.1	67.0	Co	7.9	5.1, ..,20.3	0.37, ..,0.70
4/78	9	700,700,700	9.6	184	8.2	95.0	Co,Si	15.5	20.3,25.4,10.2	0.37,0.58,0.43
6/78	12	..,550,..	8.2	136	8.2	7.0	..	..	..	..
7/78	21	680,680,750	7.5	183	8.7	8.0	Co,Gr	6.7	20.3,30.5,15.2	0.61,1.0,0.70
8/78	19	700,700,750	10.2	178	8.7	1.2	Co	7.0	15.2,40.6,10.2	0.43,0.73,0.40
10/78	7	..,780, ..	10.2	170	8.0	1.0	Co	10.7	17.8,38.1,22.9	0.24,0.18,0.21
4/79	12	600,600,1000	9.5	179	7.5	103.0	Gr	12.6	25.4,27.9,35.6	0.70,1.1,0.64
5/79	12	450	8.2	219	8.0	140.0	Gr	..	..	..
6/79	11	675	8.5	232	8.4	46.0	..	..	..	..
7/79	19	500	7.6	164	8.7	19.0	Gr	11.2	25.4,43.2,48.3	0.88,0.85,0.79
8/79	18	788	7.6	229	8.1	9.0	Sa,Gr	8.6	19.1,35.6,40.6	0.64,0.70,0.85
10/79	9	825	8.0	178	7.9	20.5	Sa,Gr	8.1	17.8,25.4,30.5	0.67,0.61,0.88
4/80	11	1200	8.1	341	8.4	725	Gr,Sa,Co	10.2	30.5,51.2,45.7	1.3,1.1,1.2
5/80	13	710	8.5	330	8.3	150	Co,Si	..	..	..
6/80	15	362	9.5	160	8.1	0.59	..	..	..	..
7/80	19	820	8.4	285	8.3	8.5	Sa,Co	9.2	13.7,28.7,21.9	0.69,0.74,0.67
8/80	20	700	9.7	250	8.3	28.0	Gr,Si	11.7	15.2,21.3,33.5	0.61,1.0,0.60
10/80	8	837	10.2	175	7.0	..	Co,Si	11.0	52.7,39.0,22.6	0.83,0.84,0.93

[1/] Substrate abbreviations: Gr = Gravel; Sa = Sand; Oe = Detritus; Co = Cobble; Si = Silt

[2/] When water conditions permitted, three measurements were taken at the left, center, and right portions of the river (facing upstream)

B. Water Quality Measurements

1. Objectives and Rationale

Water quality strongly influences the many potential uses of the White River and the distribution and abundance of White River biota. Any change in water quality resulting from project activities must be adequately and quickly detected by the MDP Aquatic Monitoring Program. Measurement of certain key chemical parameters at stations along the White River upstream and downstream from the influx of water from the project site provides a good index of water quality. These parameters were selected on the basis of results obtained during baseline studies and represent the best indicators of natural variability in White River water quality. Similar measurements for other surface waters of the site are obtained during hydrology studies (Section 5).

2. Methods

Methods used to collect and analyze water quality samples were described in RBOSC MDP Monitoring Report 1 and are not repeated herein.

3. Results and Discussion

Station 27 (upstream of Yellow Creek confluence) water quality data for 1977-1978 and 1980 MDP studies are presented in Tables 4-8, 4-9, and 4-10, respectively. Similarly, Station 29 (downstream of Yellow Creek confluence) data for the same years are presented in Tables 4-11, 4-12, and 4-13. A summary of Station 27 and 29 water quality data obtained during baseline studies (1974-1976) is presented in Tables 4-14 and 4-15, respectively.

Data in Tables 4-8 through 4-15 indicate no substantial changes from baseline conditions in White River water quality. Increases in sulfate, silicate and fluoride concentrations did occur in 1980. However, these values did not surpass the baseline means and were similar at Stations 27 and 29.

Table 4-8. Water Quality Data for Station 27 (White River), RBOSC MDP Aquatic Monitoring Studies, October 1977-October 1978

Parameter[1]	Station 27											
	10/77		4/78		6/78		7/78		8/78		10/78	
	A	B	A	B	A	B	A	B	A	B	A	B
Boron (B)	<0.5	....	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.7	....
Calcium (Ca)	84	83	72	70	37	37	65	67	69	69	67	67
Chloride (Cl)	43	43	29	29	16	12	25	24	34	33	32	32
Fluoride (F)	0.17	0.17	0.27	0.26	0.18	0.12	0.23	0.23	0.28	0.29	0.26	0.22
Magnesium (Mg)	28	31	24	24	13	12	20	19	23	26	20	20
Nitrate (N)	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Phosphorus, Ortho (P)	0.01	<0.01	0.01	0.01	0.06	0.22	0.03	0.03	<0.01	<0.01	<0.01	0.01
Phosphorus, Total (P)	0.02	0.01	0.02	0.02	0.12	0.32	0.04	0.03	<0.01	0.01	<0.01	0.01
Potassium (K)	2.8	2.7	2.1	2.1	2.2	1.9	2.6	2.5	2.4	2.5	2.1	2.2
Silica (Si)	8.3	8.3	6.2	6.4	5.9	5.7	8.4	8.3	6.9	6.7	6.9	6.9
Sodium (Na)	67	66	47	47	42	31	40	39	46	47	47	47
Solids, Total	512	529	441	446	392	279	401	354	447	450	419	413
Sulfate (S)	60	60	48	50	20	17	38	39	46	47	44	45

[1] Concentration of dissolved fraction in mg/l unless otherwise noted

Table 4-9. Water Quality Data for Station 27 (White River), RBOSC MDP Aquatic Monitoring Studies, April 1979-October 1979

Parameter[1/]	Station 27											
	4/79		5/79		6/79		7/79		8/79		10/79	
	A	B	A	B	A	B	A	B	A	B	A	B
Boron (B)	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Calcium (Ca)	57	60	41	39	49	51	73	74	71	72	72	74
Chloride (Cl)	21	22	<0.4	6.7	5.9	13	19	18	31	32	38	35
Fluoride (F)	0.14	0.16	0.12	0.11	0.08	0.08	0.20	0.20	0.23	0.22	0.27	0.27
Magnesium (Mg)	19	20	11	11	15	10	19	19	25	25	26	26
Nitrate (N)	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Phosphorus, Ortho (P)	0.0	0.01	<0.01	0.01	0.05	0.05	0.08	0.07	0.02	0.02	<0.01	0.01
Phosphorus, Total (P)	0.0	0.02	0.09	0.42	0.08	0.08	0.15	0.09	0.03	0.03	0.02	0.03
Potassium (K)	2.0	2.0	1.5	1.6	1.80	1.1	2.0	2.1	2.4	2.5	2.4	2.4
Silica (Si)	6.2	6.4	5.4	5.4	11	11	15	15	16	16	12	13
Sodium (Na)	39	39	16	17	14	14	32	33	51	55	54	54
Solids, Total	379	376	211	214	191	191	380	386	494	503	495	507
Sulfate (S)	40	40	16	18	38	32	96	92	152	152	173	171

[1/] Concentration of dissolved fraction in mg/l unless otherwise noted

Table 4-10. Water Quality Data for Station 27 (White River), RBOSC MDP Aquatic Monitoring Studies, April 1980-October 1980

Parameter[1/]	Station 27											
	4/80		5/80		6/80		7/80		8/80		10/80	
	A	B	A	B	A	B	A	B	A	B	A	B
Boron (B)	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	0.3	<0.2	<0.2	<0.2
Calcium (Ca)	51	50	46	46	37	36	65	70	77	72	45	45
Chloride (Cl)	20	20	10.8	10.5	5.6	7.9	24	23	27	26	23	22
Fluoride (F)	0.25	0.28	0.08	0.08	0.06	0.07	0.21	0.14	0.30	0.32	0.4	0.3
Magnesium (Mg)	20	20	15	15	10	9.8	25	25	29	29	18	18
Nitrate (N)	0.3	0.3	<0.2	0.2	<0.2	<0.2	<0.2	0.2	0.2	<0.2	<0.2	0.2
Phosphorus, Ortho (P)	0.07	0.07	0.01	0.02	0.08	0.06	0.01	0.01	0.04	0.04	0.02	0.07
Phosphorus, Total (P)	0.08	0.08	0.02	0.02	0.09	0.09	0.83	0.94	0.06	0.06	0.02	0.07
Potassium (K)	2.5	2.4	1.7	1.7	1.4	1.4	2.6	2.4	2.8	2.8	4.4	4.7
Silica (Si)	13	13	11	13	12	12	14.1	14	16	15	8.1	10
Sodium (Na)	43	44	24	23	14	14	47	47	54	52	91	85
Solids, Dissolved	422	367	267	248	208	214	486	485	668	1472	494	556
Sulfate (S)	150	150	76	77	43	46	150	150	180	180	190	200

[1/] Concentration of dissolved fraction in mg/l unless otherwise noted

Table 4-11. Water Quality Data for Station 29 (White River), RBOSC MDP Aquatic Monitoring Studies, October 1977-October 1978

Parameter[1]	Station 29											
	10/77		4/78		6/78		7/78		8/78		10/78	
	A	B	A	B	A	B	A	B	A	B	A	B
Boron (B)	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Calcium (Ca)	74	79	72	70	37	37	66	66	69	68	67	72
Chloride (Cl)	46	46	32	32	14	12	39	41	34	35	32	33
Fluoride (F)	0.21	0.19	0.27	0.28	0.14	0.14	0.23	0.24	0.29	0.29	0.21	....
Magnesium (Mg)	31	31	26	27	13	12	19	19	23	23	20	20
Nitrate (N)	<0.2	<0.2	<0.2	<0.2	0.4	0.2	<0.2	<0.2	0.8	<0.2	<0.2	<0.2
Phosphorus, Ortho (P)	<0.01	<0.01	0.01	0.01	0.05	0.07	0.02	0.03	<0.01	<0.01	<0.01	<0.01
Phosphorus, Total (P)	<0.01	0.02	0.02	0.02	0.25	0.17	0.03	0.03	0.02	0.04	<0.01	<0.01
Potassium (K)	2.9	3.0	2.2	2.3	2.0	2.0	2.5	2.4	2.5	2.5	2.3	2.2
Silica (Si)	8.1	8.4	6.4	6.2	5.8	5.7	8.5	8.6	8.7	6.8	6.8	7.1
Sodium (Na)	110	100	61	66	35	30	39	39	48	48	48	47
Solids, Total	625	622	490	475	329	302	432	452	458	462	426	430
Sulfate (S)	63	64	50	52	18	14	39	40	47	46	45	46

[1] Concentration of dissolved fraction in mg/l unless otherwise noted

Table 4-12. Water Quality Data for Station 29 (White River), RBOSC MDP Aquatic Monitoring Studies, April 1979-October 1979

Parameter[1]	Station 29											
	4/79		5/79		6/79		7/79		8/79		10/79	
	A	B	A	B	A	B	A	B	A	B	A	B
Boron (B)	<0.5	0.6	<0.5	1.2	<0.5	<0.5	<0.5	<0.5	<0.05	<0.5	<0.5	<0.5
Calcium (Ca)	58	62	43	39	49	48	72	73	72	72	71	70
Chloride (Cl)	19	42	16.2	16.2	13	13	19	19	31	32	39	39
Fluoride (F)	0.16	0.17	0.23	0.23	0.18	0.19	0.21	0.21	0.22	0.22	0.29	0.32
Magnesium (Mg)	20	19	21	21	15	14	19	19	25	25	27	27
Nitrate (N)	<0.2	<0.2	4.3	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Phosphorus, Ortho (P)	<0.01	<0.01	0.01	<0.01	0.06	0.05	0.08	0.08	0.02	0.02	<0.01	<0.01
Phosphorus, Total (P)	0.02	0.02	0.03	0.03	0.08	0.08	0.15	0.18	0.03	0.03	0.01	0.02
Potassium (K)	1.9	2.2	2.0	2.0	1.4	1.4	2.0	2.0	2.8	2.7	2.5	2.5
Silica (Si)	5.8	6.2	5.5	5.5	11	11	15	14	17	19	12	12
Sodium (Na)	43	45	77	77	61	55	33	33	64	62	59	60
Solids, Total	397	395	371	425	320	321	384	371	488	482	509	497
Sulfate (S)	40	42	33	33	64	60	103	101	152	155	171	174

[1] Concentration of dissolved fraction in mg/l unless otherwise noted

Table 4-13. Water Quality Data for Station 29 (White River), RBOSC MDP Aquatic Monitoring Studies, April 1980-October 1980

Parameter[1/]	Station 29											
	4/80		5/80		6/80		7/80		8/80		10/80	
	A	B	A	B	A	B	A	B	A	B	A	B
Boron (B)	<0.2	<0.2	0.3	0.2	0.5	0.2	<0.2	<0.2	0.2	<0.2	<0.2	<0.2
Calcium (Ca)	51	50	44	44	37	36	66	64	70	76	43	44
Chloride (Cl)	21	21	30.8	28.7	11.5	11.8	26	26	27	27	24	24
Fluoride (F)	0.25	0.25	0.33	0.36	0.12	0.14	0.16	0.28	0.30	0.30	0.40	0.40
Magnesium (Mg)	20	20	28	28	13	13	30	34	28	28	18	19
Nitrate (N)	0.3	0.4	0.3	0.3	0.21	0.27	0.2	<0.2	<0.2	<0.2	0.2	<0.2
Phosphorus, Ortho (P)	0.07	0.07	0.02	0.02	0.09	0.08	0.01	0.01	0.03	0.03	0.05	0.04
Phosphorus, Total (P)	0.07	0.08	0.02	0.02	0.14	0.13	0.80	0.94	0.05	0.06	0.05	0.05
Potassium (K)	2.5	2.6	2.9	2.9	1.6	1.6	2.9	2.9	2.7	2.8	4.7	4.6
Silica (Si)	13	13	13	13	12	11	12.6	13.2	16	15	8.6	8.8
Sodium (Na)	42	41	130	130	35	37	89	90	54	54	84	92
Solids, Dissolved	407	418	610	602	182	207	511	532	525	537	504	560
Sulfate (S)	155	154	164	175	63	63	160	166	160	180	200	200

[1/] Concentration of dissolved fraction in mg/l unless otherwise noted

Table 4-14. Summary of Water Quality Data for Station 27 on the White River, RBOSC Baseline Studies (October 1974 through September 1976)

Parameter[1/]	No. of Analyses	Maximum	Minimum	Mean	S.D.
Calcium (Ca)	24	88	36	69.6	1.16
Chloride (Cl)	24	39	8	31.7	1.35
Fluoride (F)	4	0.30	0.27	0.28	1.42
Magnesium (Mg)	24	34	10	25.1	1.30
Nitrate (N)	24	<0.2	<0.2	<0.2	1.80
Phosphorus, Ortho (P)	24	0.04	0.01	0.01	1.74
Phosphorus, Total (P)	24	0.45	0.02	0.06	2.22
Potassium (K)	24	4.0	1.3	2.3	1.37
Silica (Si)	24	18	9	13.2	1.17
Sodium (Na)	24	76	12	57.4	1.54
Solids, Total	24	629	192	481.5	1.38
Sulfate (S)	24	192	39	154.2	1.31

[1/] Concentration of dissolved fraction in mg/l unless otherwise noted

Table 4-15. Summary of Water Quality Data for Station 29 on the White River, RBOSC Baseline Studies (October 1974 through September 1976)

Parameter[1/]	No. of Analyses	Maximum	Minimum	Mean	S.D.
Calcium (Ca)	24	86	35	66.0	1.14
Chloride (Cl)	24	45	8	33.7	1.23
Fluoride (F)	4	0.59	0.27	0.41	1.06
Magnesium (Mg)	24	37	10	27.0	1.28
Nitrate (N)	24	2.00	0.15	0.26	1.84
Phosphorus, Ortho (P)	24	0.06	0.01	0.02	1.57
Phosphorus, Total (P)	24	0.55	0.02	0.05	2.57
Potassium (K)	24	4.3	1.4	2.3	1.33
Silica (Si)	24	18	10	13.0	1.15
Sodium (Na)	24	138	17	66.7	1.27
Solids, Total	24	699	205	471.5	1.22
Sulfate (S)	24	213	42	157.3	1.24

[1/] Concentration of dissolved fraction in mg/l unless otherwise noted

Sodium concentrations were slightly higher at Station 29 than at Station 27 in 1980. This is due to the contribution of sodium by Yellow Creek. No substantial differences in water quality were recorded at either Station 27 or 29 since the initiation of project activities. The concentration of the water quality parameters measured at Stations 27 and 29 were within the range recorded for unpolluted U.S. rivers (Table 4-16).

Table 4-16. Concentrations (mg/l) of Selected Chemical Parameters in Unpolluted U.S. River Waters

Parameter	Range
Boron	0.01-1[1/]
Chloride	4-120[1/]
Fluoride	<1[2/]
Nitrate	0.01-0.8[1/]
Phosphorus	0.001-0.3[1/]
Potassium	1.4-10[1/]
Silicon	1-30[2/]
Sodium	1-100,000[2/]

[1/] Bowen, H.J.M. 1966.
[2/] Hem, J.D. 1970.

4.2 BIOTIC COMPONENTS

A. Periphyton

1. Objectives and Rationale

Sensitivity of periphyton to changes in their environment has been well documented (Cholnoky 1968; Round 1973; Lowe 1974; Hutchinson 1975; Whitton 1975; Patrick 1977). Species composition and relative abundance of the total periphyton community and key periphyton species provide good indicators of potential project effects on aquatic systems in the vicinity of Tract C-a. Periphyton communities are amenable to sampling techniques which produce a good data base for identifying changes quickly and accurately. Therefore, the study of these communities is an important part of the MDP Monitoring Program. Species composition, relative abundance, biomass and diversity are the periphyton parameters measured.

2. Methods

Methods used for identification, enumeration and biomass determinations were described in RBOSC MDP Report 4 and are not repeated herein.

3. Results and Discussion

A total of 204 taxa was identified from the periphyton samples collected during the 1980 MDP aquatic studies. Distribution of taxa among stations for all sampling periods is provided in Appendix 4-2. Seasonal changes in species occurrence at each station are presented in Appendix 4-2.1. Periphyton enumeration and biomass data for 1980 are provided in Appendices 4-2.2 and 4-2.3, respectively. Appendix 4-2.4 lists the periphyton density and species diversity estimates by sampling date for all stations surveyed during 1980. Biomass estimates for 1980 are presented in Appendix 4-2.5. Mean densities of dominant taxa (comprising $\geq$1% of the total density) collected during the RBOSC aquatic baseline studies (1974-1976) and MDP monitoring studies (1978-1980) are presented in Table 4-17 by station and sampling date. Comparison

Table 4-17. Mean Densities of the Most Abundant Algal Species (>1% of the Total Density) in the Periphyton During RBOSC MDP Studies (1978, 1979 and 1980) and RBOSC Aquatic Baseline Studies (1974-1976)

STATION/Taxa	Date	Density (Units/mm^2) 1974	1975	1976	1978	1979	1980
STATION 13	APRIL						
Achnanthes lanceolata		..	288	..	..	..	26
A. minutissima		..	..	..	..	..	31
A. spp.		..	4,481	14,765	94	905	..
Bicoeca lacustris		..	..	631	162	..	..
Fragilaria vaucheriae		..	..	..	..	364	41
Gomphonema intricatum		..	..	12,929	..	..	..
Meridion circulare		..	..	3,240	..	..	5
Navicula arvensis		..	..	..	25	..	..
N. cryptocephala vars.		..	830	2,081	14	..	3
N. pelliculosa		..	..	15,230	..	..	2
N. secreta var. apiculata		..	..	..	..	..	17
N. viridula		..	..	..	..	..	70
Nitzschia capitellata		..	..	1,008	23	..	..
N. frustulum		..	125	..	..	..	3
Synedra minuscula		..	..	..	..	78	..
Surirella ovata		..	..	..	..	..	25
Phormidium spp.		..	..	..	..	3,148	61
	MAY [1/]						
Achnanthes lanceolata		..	..	..	..	..	6
A. minutissima		..	..	..	..	..	55
A. spp.		..	..	..	..	47	..
Amphora ovalis		..	..	..	..	..	4
Fragilaria vaucheriae		..	..	..	..	..	20
Gomphonema parvulum		..	..	..	..	..	18
Hantzschia amphioxys		..	..	..	..	..	2
Navicula cryptocephala		..	..	..	..	3	..
N. minima		..	..	..	..	..	2
N. secreta var. apiculata		..	..	..	..	..	23
N. viridula		..	..	..	..	15	8
Nitzschia fonticola		..	..	..	..	..	5
N. linearis		..	..	..	..	..	6
Surirella ovalis		..	..	..	..	..	4
Synedra fasciculata		..	..	..	..	..	5
Vaucheria sp.		..	..	..	..	..	3
Phormidium sp.		..	..	..	..	170	20

Table 4-17. (Continued)

STATION/Taxa Date	Density (Units/mm^2) 1974	1975	1976	1978	1979	1980
STATION 13 - Continued						
JUNE						
Achnanthes lanceolata	..	1	8	..	..	7
A. minutissima	..	..	..	..	..	238
A. spp.	..	29	200	178	222	..
Biocoeca lacustris	..	..	71	90	..	..
Fragilaria vaucheriae	..	3	..	4	52	143
Gomphonema intricatum	..	6	10	..	..	..
Navicula cryptocephala	..	9	34	9	19	..
N. heufleri	..	..	..	..	16	4
N. pelliculosa	..	1	15	21	28	6
N. secreta var. apiculata	..	..	..	..	12	13
N. viridula	..	1	2	14	..	..
N. spp.	..	5	4	..	..	..
Nitzschia acicularis	..	2	..	..	..	..
N. dissipata	..	..	..	7	..	..
N. fonticola	..	..	..	..	152	142
N. frustulum	..	6	6	..	15	9
N. holsatica	..	..	..	..	13	..
N. palea	..	3	..	2	..	2
N. spp.	..	..	..	..	9	..
Surirella ovata	..	1	..	7	13	5
Lyngbya spp.	..	..	..	..	10	..
Phormidium spp.	..	..	..	..	441	..
Palmella Stage	..	..	..	..	..	6
JULY						
Achnanthes affinis	..	..	..	..	..	567
A. spp.	..	835	10,784	86	5,816	..
Biocoeca lacustris	..	..	600	..	..	..
Cymbella affinis	..	..	4,420	..	..	..
C. minutesta	..	..	..	..	..	47
Diatoma tenue var. elongatum	..	..	..	..	..	17
Fragilaria crotonensis	..	..	..	..	..	63
F. vaucheriae	..	80	708	..	203	201
Gomphonema intricatum	..	79	805	..	..	..
Navicula arvensis	..	28	402	..	..	1
N. cryptocephala	..	192	3,162	2	..	
N. halophila	..	..	..	..	..	19
N. pelliculosa	..	172	..	..	..	1
N. secreta var. apiculata	..	..	..	..	..	62
N. viridula	..	..	538	..	..	

Table 4-17. (Continued)

STATION/Taxa	Date	Density (Units/mm^2) 1974	1975	1976	1978	1979	1980
STATION 13 - Continued							
	JULY - Continued						
Nitzschia capitellata		..	70	1,377	..	..	..
N. frustulum		..	43	362	61	..	6
N. holsatica		..	57	..	..	..	..
N. latens		..	..	187	5	..	..
N. palea		..	55	..	..	..	..
Synedra sp.		..	..	..	..	..	74
Surirella ovata		..	11	958	..	..	5
Calothrix spp.		..	..	975	2,117	..	..
Unidentified pennate diatoms		..	..	..	..	..	21
	AUGUST						
Achnanthes affinis		..	..	..	..	..	865
A. lanceolata		..	203	57	..	..	24
A. spp.		..	2,775	2,002	3,310	3,044	1
Amphora ovalis var. pediculus		..	..	47	..	..	..
Biocoeca lacustris		..	652	78	2,188	..	..
Cymbella affinis		..	220	13	..	..	..
C. minuta		..	..	..	..	..	178
Fragilaria vaucheriae		..	98	..	..	..	21
Gomphonema intricatum		..	614	27	40	..	..
Navicula cryptocephala		..	197	63	91	..	..
N. halophila		..	..	..	..	..	61
N. pellicuolsa		..	199	15	4,297	..	4
Nitzschia denticula		..	63	5	..	..	4
N. fonticola		..	..	..	..	70	..
N. frustulum		..	22	14	18	..	46
Lyngbya spp.		..	980	..	905	..	..
Phormidium spp.		..	..	..	..	74	..
Cladophora sp.		..	..	..	..	..	126
Microspora sp.		..	..	..	..	..	41
Spirogyra sp.		..	..	..	..	..	57
Zygnema sp.		..	..	..	..	..	16

Table 4-17. (Continued)

STATION/Taxa	Date	Density (Units/mm^2) 1974	1975	1976	1978	1979	1980
STATION 13 - Continued							
	OCTOBER						
Achnanthes lanceolata		653	1,689	..	158	..	2
A. minutissima		..	..	..	..	..	227
A. spp.		5,378	11,312	..	3,864	14,889	..
Biocoeca lacustris		..	3,289	..	..	..	..
Cymbella affinis		..	290	..	..	..	..
Gomphonema intricatum		428	1,632	..	669	..	..
Meridion circulare		281	..	..	..	..	..
Navicula arvensis		281	769	..	..	..	..
N. cryptocephala		7,223	2,949	..	862	..	..
N. heufleri		..	..	..	..	..	7
N. pelliculosa		..	388	..	1,521	..	..
N. secreta var. apiculata		..	..	..	..	..	20
N. viridula		..	75	..	744	..	..
N. viridula var. avenacea		..	..	..	..	..	26
Nitzschia acicularis		79	2,110	..	..	..	1
N. capitellata		..	84	..	490	..	..
N. frustulum		158	68	..	213	..	9
N. linearis		214	25	..	..	..	..
N. palea		281	606	..	177	..	1
Surirella ovata		..	90	..	508	..	1
Lyngbya spp.		956	124	..	930	..	..
Phormidium spp.		..	..	..	..	246	..
Plectonema spp.		..	..	..	518	..	..
Batrachospermum sp.		..	..	..	..	..	142

Table 4-17. (Continued)

STATION/Taxa	Date	Density (Units/mm^2) 1974	1975	1976	1978	1979	1980
STATION 14	APRIL						
Achnanthes lanceolata		..	247	99	14	160	50
A. minutissima		..	..	..	..	..	600
A. spp.		..	4,954	573	48	5,735	..
Biocoeca lacustris		..	..	3,471	..	..	..
Cymbella affinis		..	199	..	..	..	..
Gomphonema intricatum		..	23	180	300	274	..
Navicula arvensis		..	199	177	584	2,590	..
N. cryptocephala		..	435	339	363	..	..
N. pelliculosa		..	154	957	607	315	4
N. secreta var. apiculata		..	..	..	..	200	433
N. viridula		..	168	9	..	..	17
Nitzschia capitellata		..	..	273	1,642	..	..
N. acicularis		..	..	..	..	..	30
N. denticula		..	1,688	27	..	..	..
N. frustulum		..	1,069	48	431	..	..
N. linearis		..	..	..	..	..	20
N. palea		..	171	27	..	..	..
Synedra amphicephala		..	135	..	..	..	2
S. minuscula		..	..	..	..	162	..
S. fasciculata		..	..	..	..	111	..
S. ulna		..	..	..	..	..	22
	MAY [1]						
Achnanthes lanceolata		..	..	..	..	58	120
A. minutissima		..	..	..	..	..	1,545
A. spp.		..	..	..	..	1,004	..
Gomphonema parvulum		..	..	..	..	..	287
Navicula arvensis		..	..	..	..	76	..
N. pelliculosa		..	..	..	..	..	594
N. secreta var. apiculata		..	..	..	..	59	3,449
Nitzschia acicularis		..	..	..	..	..	859
N. denticula		..	..	..	..	17	..
N. linearis		..	..	..	..	..	108
Synedra fasciculata		..	..	..	..	23	..
Unidentified pennate diatoms		..	..	..	..	18	..
Cladophora glomerata		..	..	..	..	..	1,170
Phormidium		..	..	..	..	65	..

Table 4-17. (Continued)

STATION/Taxa	Date	Density (Units/mm^2) 1974	1975	1976	1978	1979	1980
STATION 14 - Continued							
	JUNE						
Achnanthes affinis		..	..	..	0[1/]	..	94
A. lanceolata		..	..	..	..	129	73
A. minutissima		..	..	..	..	..	194
A. spp.		..	6,390	4,245	..	1,340	..
Biocoeca lacustris		..	..	6,570	..	..	..
Cyclotella menegheniana		..	..	59	..	65	1
Cymbella affinis		..	553	37	..	..	..
Diatoma vulgare var. grande		..	..	..	..	408	..
Fragilaria vauchepiae		..	..	..	..	..	121
F. sp.		..	..	..	..	55	..
Navicula cryptocephala		..	279	131	..	77	1
N. cryptocephala var. veneta		..	..	..	..	..	18
N. secreta var. apiculata		..	..	..	..	323	..
N. heufleri		..	..	..	..	..	16
Nitzschia denticula		..	4,013	157	..	301	1
N. fonticola		..	..	..	..	89	12
N. frustulum		..	313	22	..	..	48
Pinnularia brebissoni		..	..	..	..	..	13
Synedra amphicephala		..	176	20	..	..	..
S. famelica		..	..	..	..	1,198	..
S. fasciculata		..	..	..	..	827	18
S. minuscula		..	..	..	..	..	25
S. ulna		..	255	50	..	..	2
Merismopedia glauca		..	1,005	..	..	..	
	JULY						
Achnanthes affinis		..	..	..	..	..	306
A. lanceolata		..	..	..	0[1/]	113	31
A. spp.		..	8,160	1,547	..	880	..
Ailanceolata var. dubia		..	..	..	..	..	34
A. minutissima		..	..	..	..	..	389
Cymbella affinis		..	1,481	..	..	..	..
C. minuta		..	..	..	..	33	34
C. minuta var. silesica		..	..	..	..	..	68
Cyclotella meneghiniana		..	7	21	..	..	56
Diatoma tenue var. elongatum		..	..	..	..	..	112
D. vulgare		..	..	..	..	..	35

Table 4-17. (Continued)

STATION/Taxa	Date	Density (Units/mm^2) 1974	1975	1976	1978	1979	1980
STATION 14 - Continued							
	JULY - Continued						
Epithemia sorex		..	..	..	..	..	59
Fragilaria vaucheriae		..	108	..	..	32	511
F. crotonensis		..	..	..	..	..	475
Navicula cryptocephala		..	315	175	..	39	..
N. halophila		..	..	..	..	..	59
N. heufleri		..	..	..	..	..	42
N. secreta var. apiculata		..	..	..	..	279	448
N. tripunctata		..	..	35	..	..	..
Nitzschia acicularis		..	180	..	..	..	13
N. denticula		..	2,124	112	..	47	..
N. fonticola		..	..	..	..	48	..
N. frustulum		..	73	329	..	..	83
N. holsatica		..	729	..	..	..	..
N. linearis		..	..	..	..	..	36
Rhoicosphenia curvata		..	..	..	..	..	35
Rhopalodia gibba		..	..	49	..	..	..
R. gibberula		..	..	63	..	..	2
Surirella ovata		..	..	..	..	22	11
Synedra acus		..	..	..	..	..	73
S. minuscula		..	360	..	..	257	..
S. fasciculata		..	..	..	..	86	96
S. minuscula		..	658	7	..	..	37
S. ulna		..	495	..	..	..	..
Thalassiosira fluriatilis		..	..	..	..	..	52
Unidentified pennate diatoms		..	..	..	..	44	52
Plectonema spp.		..	1,102	..	..	..	..
	AUGUST						
Achnanthes affinis		..	..	..	..	..	269
A. lanceolata		..	20	56	..	..	228
A. microcephala		..	..	..	..	..	82
A. minutissima		..	..	..	..	..	3,240
A. spp.		..	3,191	686	35	1,887	..
Amphora ovalis var. pediculus		..	..	70	..	..	..
Cocconeis placentula		..	..	35	1	..	92
Cyclotella meneghiniana		..	211	..	..	..	745
Cymbella affinis		..	4,140	21	..	..	..
C. cymbiformis		..	..	..	..	72	..
C. microcephala		..	226	..	..	..	..
C. minuta		..	..	..	..	90	44
C. ventricosa		..	208	7	1	..	..

Table 4-17. (Continued)

STATION/Taxa Date	Density (Units/mm^2) 1974	1975	1976	1978	1979	1980
STATION 14 - Continued						
AUGUST - Continued						
Diatoma tenue var. elongatum	..	..	..	..	90	78
D. vulgare var. grande	..	..	..	..	71	..
Fragilaria capucina	..	..	..	..	322	122
F. crotonensis	..	..	..	..	..	301
F. vaucheriae	..	..	..	..	85	352
Navicula cryptocephala	..	165	203	5	..	29
N. pelliculosa	..	14	28	4	..	8
N. secreta var. apiculata	..	..	..	..	232	515
Nitzschia capitellata	..	..	..	1	..	..
N. denticula	..	1,969	21	1	222	..
N. fonticola	..	..	..	..	88	..
N. frustulum	..	27	203	2	..	256
N. holsatica	..	..	811	..	109	..
N. palea	..	14	91	1	..	..
Rhoicosphenia curvata	..	..	42	..	..	..
Rhopalodia gibberula	..	..	119	..	..	..
Synedra amphicephala	..	..	..	1	..	..
S. minuscula	..	..	..	..	992	..
S. fasciculata	..	..	..	..	322	193
S. spp.	..	..	..	..	71	..
Thalassiosira fluriatilis	..	..	..	..	..	266
Unidentified pennate diatom	..	..	..	..	122	..
OCTOBER						
Achnanthes lanceolata	2	3	..	..	..	329
A. lanceolata var. dubia	..	..	..	..	..	38
A. minutissima	..	..	..	..	..	2,416
A. spp.	641	491	..	65	131	..
Cyclotella meneghiniana	..	10	..	2	4,395	14
Cymbella affinis	..	54	..	..	1,362	..
C. microcephala	..	22	..	..	..	..
C. minuta	..	..	..	..	123	4
Fragilaria vaucheriae	4	1	..	5	166	..
Gomphonema intricatum	..	..	..	4	110	..

Table 4-17. (Continued)

STATION/Taxa Date	Density (Units/mm^2) 1974	1975	1976	1978	1979	1980
STATION 14 - Continued						
OCTOBER - Continued						
Navicula cryptocephala	9	20	..	5	..	..
N. heufleri	..	..	..	..	..	34
N. pelliculosa	..	..	..	..	109	9
N. secreta var. apiculata	..	..	..	..	269	230
Nitzschia denticula	..	..	..	..	365	..
N. frustulum	34	..	..	5	..	178
N. palea	9	1	..	9	..	4
N. spp.	..	..	..	..	163	..
N. sp. #1	..	..	..	..	112	..
Synedra amphicephala	11	..	..	6	..	..
S. minuscula	..	..	..	..	1,184	..
S. fasciculata	..	..	..	..	362	..
S. ulna	22	..	..	42	..	..
Thalassiosira fluviatilis	..	..	..	..	140	..
Unidentified pennate diatoms	..	..	..	..	123	9
Lyngbya spp.	..	..	..	3	..	..
STATION 20 APRIL						
Achnanthes lanceolata	..	..	..	..	..	4
A. minutissima	..	..	..	..	..	22
A. spp.	..	1,337	6	6,226	..	..
Cymbella affinis	..	72	..	..	..	..
Diatoma hiemale	..	..	..	..	..	3
Fragilaria capucina	..	..	..	..	..	19
F. vaucheriae	..	108	48	10	262	35
Gomphonema olivaceum	..	13	9	..	35	1
Navicula pelliculosa	..	518	1,334	21,965	729	24
N. cryptocephala	..	..	..	..	..	4
N. cryptocephala var. veneta	..	..	..	..	..	3
N. secreta var. apiculata	..	..	..	..	..	8
Nitzschia capitellate	..	..	190	3	..	..
N. fonticola	..	..	..	..	232	2
N. frustulum	..	32	18	1,635	..	1
N. holsatica	..	..	80	..	475	16
N. microcephala	..	..	..	355	..	..
N. palea	..	45	84	909	..	9
N. spp.	..	..	..	..	29	..

Table 4-17. (Continued)

STATION/Taxa Date	Density (Units/mm^2) 1974	1975	1976	1978	1979	1980
STATION 20 - Continued						
APRIL - Continued						
Surirella ovata	..	243	1,035	52	280	68
Synedra amphicephala	..	9	1,350	2	..	..
S. minuscula	..	..	..	..	26	..
Sulfur bacterium	..	..	..	..	..	2,637
MAY [1/]						
Achnanthes lanceolata	..	..	..	..	..	6
A. minutissima	..	..	..	..	..	35
A. spp.	..	..	..	..	38	..
Entomoneis paludosa	..	..	..	..	..	2
Fragilaria vaucheriae	..	..	..	..	10	41
Navicula pelliculosa	..	..	..	..	242	4
N. secreta var. apiculata	..	..	..	..	..	5
Nitzschia fonticola	..	..	..	..	168	5
N. frustulum	..	..	..	..	29	..
N. holsatica	..	..	..	..	14	10
Surirella ovata	..	..	..	..	8	21
Synedra minuscula	..	..	..	..	..	2
Sulfur bacterium	..	..	..	..	509	132
JUNE						
Achnanthes affinis	..	..	..	..	..	250
A. lanceolata	..	..	..	..	..	52
A. lanceolata var. dubia	..	..	..	..	..	237
A. spp.	..	5,011	37	106	177	..
Bicoeca lacustris	..	..	26	..	..	..
Cyclotella meneghiniana	..	74	70	20	23	204
Cymbella ventricosa	..	61	..	..	..	..
Fragilaria vaucheriae	..	..	..	..	16	61
Navicula cryptocephala	..	13	7	..	8	7
N. secreta var. apiculata	..	..	..	..	..	24
N. pelliculosa	..	22	9	..	46	..
Nitzschia fonticola	..	..	..	..	371	137
N. frustulum	..	3	414	119	..	65
N. holsatica	..	..	..	..	8	..
N. latens	..	..	14	..	13	5

Table 4-17. (Continued)

STATION/Taxa	Date	Density (Units/mm^2) 1974	1975	1976	1978	1979	1980
STATION 20 - Continued							
	JUNE - Continued						
Surirella ovata		..	6	12	..	..	55
Calothrix spp.		..	19	26	1,030	..	..
Lyngbya spp.		..	144	9	..	9	..
Phormidium spp.		..	..	..	..	24	..
Bulbochaeta		..	..	..	..	..	909
Sulfur bacterium		..	..	..	..	..	637
	JULY						
Achnanthes affinis		..	..	..	..	..	866
A. spp.		..	84	36	86	..	13,
Cyclotella meneghiniana		..	24	162	18	15	443
Cymbella pusilla		..	..	21	13	..	..
C. ventricosa		..	24	3	..	..	..
Gomphonema olivaceum		..	25	..	..	..	..
Mastogloia elliptica		..	..	71	2	3	..
Navicula cryptocephala		..	111	36	2	..	..
N. pelliculosa		..	122	..	..	..	..
N. viridula		..	35	99	..	..	4
Nitzschia fonticola		..	128	9	..	22	..
N. frustulum		..	64	747	61	..	11
N. holsatica		..	32	111	..	2	..
N. latens		..	..	38	5	..	..
N. microcephala		..	3	15	22	..	..
Synedra pulchella		..	..	..	..	4	..
S. pulchella var. lanceolata		..	..	..	..	..	344
Unidentified pennate diatoms		..	..	..	..	1	..
Bulbochaetae spp.		..	..	..	..	72	1,583
Calothrix spp.		..	2	177	2,117	..	..
Cladophora spp.		..	2	25	..	..	491
Sulfur bacterium		..	..	..	..	..	757

Table 4-17. (Continued)

STATION/Taxa Date	Density (Units/mm^2) 1974	1975	1976	1978	1979	1980
STATION 20 - Continued						
AUGUST						
Achnanthes affinis	..	..	..	..	..	3,019
A. spp.	..	1,132	123	86	20	2
Cyclotella meneghiniana	..	4	78	18	63	40
Cymbella ventricosa	..	28	..	..	..	..
C. sp. #1	..	..	82	..	..	..
Fragilaria capucina	..	..	..	..	3	..
Gomphonema intricatum	..	..	..	..	9	2
Mastogloia elliptica	..	..	157	2	..	..
Navicula cryptocephala	..	12	250	2	15	4
N. viridula	..	..	..	..	7	..
Nitzschia capitellata	..	..	93	..	..	..
N. fonticola	..	20	..	..	12	..
N. frustulum	..	24	3,196	61	..	16
N. holsatica	..	..	310	..	..	..
N. microcephala	..	..	..	22	4	..
N. palea	..	42	..	..	..	..
N. latens	..	..	142	5	..	..
N. spp.	..	..	..	..	100	1
Synedra pulchella	..	..	63	2	..	..
S. pulchella var. lanceolata	..	..	..	..	..	56
Calothrix spp.	..	..	..	2,117	..	..
Bulbochaeta sp.	..	..	..	..	..	557
Cladophora sp.	..	..	..	..	..	278
OCTOBER						
Achnanthes affinis	..	..	..	..	..	2,927
A. spp.	7,718	7,629	..	49	478	..
Cyclotella meneghiniana	855	60	..	117	..	103
Cymbella affinis	7,830	..	..	..	..	..
C. minuta var. silesiaca	..	..	..	..	..	74
C. pusilla	23	330	..	3	..	..
Navicula cryptocephala	214	131	..	6	..	..
N. sp. #1	..	30	..	119	..	..
N. viridula	..	8	..	74	..	..
Nitzschia frustulum	124	356	..	295	..	52
N. holsatica	..	..	..	41	..	..
N. latens	..	27	..	183	..	..
N. microcephala	..	4	..	97	..	..
N. palea	45	203	..	33	..	..

Table 4-17. (Continued)

STATION/Taxa	Date	Density (Units/mm^2) 1974	1975	1976	1978	1979	1980
STATION 20 - Continued							
	OCTOBER - Continued						
Surirella ovata		..	..	..	43	..	9
Thalassiosira fluviatilis		..	4	..	73	..	..
Calothrix spp.		2,059	..	..	..	..	..
Bulbochaeta sp.		..	..	..	..	..	1,094
STATION 21							
	APRIL						
Achnanthes lanceolata		..	..	..	..	8	1
A. spp.		..	977	114	807	19	..
Fragilaria capucina		..	..	..	..	..	7
F. vaucheriae		..	162	118	4	106	26
Gomphonema olivaceum		..	9	..	..	11	1
Navicula cryptocephala		..	13	26	49	10	3
N. pelliculosa		..	3,996	547	15,634	75	1
Nitzschia capitellata		..	..	283	4	..	..
N. fonticola		..	..	..	..	25	1
N. frustulum		..	40	18	851	15	1
N. holsatica		..	..	136	..	52	6
N. microcephala		..	..	..	172	..	..
N. palea		..	58	12	1,791	..	1
N. spp.		..	..	..	..	9	1
Surirella ovata		..	266	1,276	219	124	69
S. ovalis		..	..	..	..	54	1
Synedra amphicephala		..	9	1,149	..	..	..
Sulfur bacterium		..	..	..	..	..	468

Table 4-17. (Continued)

STATION/Taxa Date	Density (Units/mm^2) 1974	1975	1976	1978	1979	1980
STATION 21 - Continued						
MAY [1]						
Achnanthes lanceolata	..	..	..	..	..	12
A. minutissima	..	..	..	..	..	20
A. spp.	..	..	..	..	14	..
Cyclotella meneghiniana	..	..	..	..	..	6
Entomoneis paludosa	..	..	..	..	..	4
Fragilaria vaucheriae	..	..	..	..	10	84
Navicula pelliculosa	..	..	..	..	203	..
N. secreta var. apiculata	..	..	..	..	..	12
Nitzschia fonticola	..	..	..	..	99	6
N. frustulum	..	..	..	..	15	..
N. holsatica	..	..	..	..	9	5
N. linearis	..	..	..	..	..	5
Surirella ovata	..	..	..	..	5	84
Microspora sp.	..	..	..	..	..	4
Sulfur bacterium	..	..	..	..	..	138
JUNE						
Achnanthes affinis	..	..	..	..	..	18
A. lanceolata var. dubia	..	..	..	..	..	63
A. spp.	..	2,142	753	50	22	..
Cyclotella meneghiniana	..	86	446	60	24	243
Cymbella ventricosa	..	38	..	..	..	..
Fragilaria vaucheriae	..	..	52	..	8	51
Navicula cryptocephala	..	20	52	13	5	2
N. pelliculosa	..	12	22	..	18	..
N. secreta var. apiculata	..	..	..	..	..	19
Nitzschia fonticola	..	..	..	..	225	29
N. frustulum	..	180	406	42	5	109
N. microcephala	..	43	..	8	..	..
N. palea	..	135	..	3	..	8
N. sp. #1	..	..	..	..	4	..
Rhopalodia gibberula	..	..	..	32	..	..
Surirella ovata	..	5	147	1	..	84
Synedra pulchella	..	5	125	108	..	..
Calothrix spp.	..	..	..	941	..	..
Dactylococcopsis spp.	..	9	..	..	39	..
Lyngbya spp.	..	108	31	..	..	..

Table 4-17. (Continued)

STATION/Taxa Date	Density (Units/mm^2) 1974	1975	1976	1978	1979	1980
STATION 21 - Continued						
JUNE - Continued						
Phormidium spp.	..	..	..	..	5	..
Plectonema spp.	..	596	..	..	..	..
Cladophora spp.	..	..	273	..	..	..
Mougeotia spp.	..	..	..	32	..	..
Bulbochaeta sp.	..	..	..	..	..	776
JULY						
Achnanthes affinis	..	..	..	..	..	1,263
A. spp.	..	281	37	46	..	..
Amphora ovalis var. pediculus	..	192	2	1	..	..
Cyclotella meneghiniana	..	19	157	45	62	718
Cymbella pusilla	..	..	25	2	..	..
Fragilaria vaucheriae	..	..	..	..	..	14
Gomphonema olivaceum	..	97	..	..	..	..
Mastogloia elliptica	..	..	78	3	..	..
Navicula cryptocephala	..	158	145	10	..	..
Nitzschia fonticola	..	291	..	..	140	..
N. frustulum	..	100	789	120	..	14
N. holsatica	..	51	12	..	11	..
N. microcephala	..	37	8	50	8	..
N. palea	..	59	..	2	..	..
Rhopalodia gibberula	..	..	25	13	..	..
Synedra pulchella	..	..	..	..	11	..
S. pulchella var. lanceolata	..	..	..	..	..	630
S. ulna	..	142	5	..	..	..
Calothrix spp.	..	48	131	3,433	..	..
Lyngbya spp.	..	456	..	..	..	..
Bulbochaetae spp.	..	..	..	..	284	2,965
Cladophora spp.	..	..	32	..	..	198

Table 4-17. (Continued)

STATION/Taxa Date	Density (Units/mm^2) 1974	1975	1976	1978	1979	1980
STATION 21 - Continued						
AUGUST						
Achnanthes affinis	..	..	..	..	..	1,522
A. spp.	..	653	101	7	12	..
Cyclotella meneghiniana	..	20	41	74	57	44
Cymbella pusilla	..	..	..	52	..	..
C. ventricosa	..	15	..	52	..	..
Gomphonema intricatum	..	39	..	..	9	..
G. parvulum	..	..	..	..	19	..
Navicula cryptocephala	..	..	238	9	12	..
N. viridula	..	16	..	13	..	..
Nitzschia fonticola	..	..	..	..	174	..
N. frustulum	..	98	14,004	55	..	4
N. holsatica	..	18	244	4	17	..
N. latens	..	117	619	2	..	..
N. microcephala	..	..	45	42	16	..
N. spp.	..	..	..	..	14	4
N. sp. #1	..	..	..	..	312	..
Synedra pulchella var. lanceolata	..	..	..	..	..	75
Calothrix spp.	..	10	15	2,263	..	..
Lyngbya spp.	..	17	..	5	..	..
Phormidium spp.	..	..	..	..	10	..
Bulbochaeta sp.	..	..	..	..	..	767
Cladophora sp.	..	..	..	..	..	182
OCTOBER						
Achnanthes affinis	..	..	..	..	..	1,821
A. spp.	5,996	6,464	..	3	789	..
Amphora coffeiformis	..	..	..	..	..	46
Cyclotella meneghiniana	236	9	..	36	19	56
Cymbella affinis	9,034	..	..	..	..	..
C. minuta	..	..	..	..	..	32
C. minuta var. silesiaca	..	..	..	..	..	66
C. pusilla	113	81	..	1	..	..
Gomphonema intricatum	11	71	..	1	..	..
Navicula cryptocephala	45	29	..	9	13	..
N. sp. #1	..	4	..	76	..	..
N. viridula	..	8	..	44	..	..

Table 4-17. (Continued)

STATION/Taxa Date	Density (Units/mm^2) 1974	1975	1976	1978	1979	1980
STATION 21 - Continued						
OCTOBER - Continued						
Nitzschia capitellata	..	..	..	14	..	..
N. fonticola	..	..	..	..	10	..
N. frustulum	68	48	..	188	..	12
N. holsatica	..	..	..	15	..	4
N. latens	..	4	..	102	..	..
N. microcephala	..	..	..	49	..	..
N. palea	101	45	..	8	..	..
N. sp. #1	..	..	..	..	33	..
Surirella ovata	..	5	..	18	..	3
Synedra pulchella var. lanceolata	..	..	..	..	..	50
Thalassiosira fluviatilis	..	..	..	36	..	..
Calothrix spp.	540	..	..	..	..	..
Phormidium spp.	..	..	..	..	25	..
Bulbochaeta sp.	..	..	..	..	..	507
Enteromorpha sp.	..	..	..	..	..	56
STATION 27 APRIL						
Achnanthes minutissima	..	..	..	..	..	50
A. spp.	..	202	102	22	40	..
Amphora ovalis var. pediculus	..	360	1,632	8	..	..
Cymbella minuta	..	..	..	..	19	5
Epithemia sorex	..	911	1,371	..	110	252
Gomphonema olivaceum	..	675	634	2,944	292	64
Navicula cryptocephala	..	2,328	1,145	401	44	102
N. pelliculosa	..	79	..	1,951	35	1
N. tripunctata	..	1,463	816	26	..	2
N. viridula	..	2,014	4,477	402	44	956
Nitzschia dissipata	..	1,957	1,519	258	29	168
N. fonticola	..	..	..	..	16	4
N. frustulum	..	168	997	18	15	11
N. holsatica	..	..	..	..	15	..
N. palea	..	..	..	..	..	19
Rhoicosphenia curvata	..	..	..	..	19	27

Table 4-17. (Continued)

STATION/Taxa	Date	Density (Units/mm^2) 1974	1975	1976	1978	1979	1980
STATION 27 - Continued							
	APRIL - Continued						
Surirella ovata		..	540	57	18	..	21
Calothrix spp.		..	124	1,020	..	..	..
Phormidium spp.		..	..	..	..	143	4
	MAY [1]						
Achnanthes minutissima		..	..	..	..	0[1]	6
Amphora perpusilla		..	..	..	..	..	8
Cocconeis placentula		..	..	..	..	..	6
Epithemia sorex		..	..	..	..	..	162
Fragilaria vaucheriae		..	..	..	..	..	11
Gomphonema olivaceum		..	..	..	..	..	5
Navicula notha		..	..	..	..	..	15
N. secreta var. apiculata		..	..	..	..	..	4
N. viridula		..	..	..	..	..	32
Nitzschia fonticola		..	..	..	..	..	6
N. frustulum		..	..	..	..	..	11
N. holsatica		..	..	..	..	..	7
N. palea		..	..	..	..	..	4
Unidentified pennate diatoms		..	..	..	..	..	5
Microspora sp.		..	..	..	..	..	10
Spirogyra sp.		..	..	..	..	..	4
Phormidium sp.		..	..	..	..	..	30
	JUNE						
Achnanthes spp.		..	306	181	0[1]	0[1]	0[1]
Amphora ovalis var. pediculus		..	1,914	2,278	..	..	..
Cymbella sinuata		..	589	125	..	..	..
C. ventricosa		..	65	249	..	..	..
Epithemia sorex		..	..	234	..	..	..
Fragilaria vaucheriae		..	..	272	..	..	..
Gomphonema olivaceum		..	..	1,133	..	..	..

Table 4-17. (Continued)

STATION/Taxa Date	Density (Units/mm^2) 1974	1975	1976	1978	1979	1980
STATION 27 - Continued						
JUNE - Continued						
Navicula cryptocephala	..	121	2,289	..	..	..
N. pelliculosa	..	2,090	159	..	..	..
N. tripunctata	..	2	567	..	..	..
N. vaucheriae	..	252	..	..	..	..
N. viridula	..	..	467	..	..	..
Nitzschia dissipata	..	50	1,802	..	..	..
N. frustulum	..	263	1,496	..	..	..
Calothrix spp.	..	..	137	..	..	..
Lyngbya spp.	..	36	771	..	..	..
JULY						
Achnanthes minutissima	..	..	..	..		197
A. spp.	..	30	45	180	17	..
Amphora ovalis var. pediculus	..	365	5,269	569	..	..
A. perpusilla	..	..	..	..	42	69
Biocoeca lacustris	..	233	..	..	..	..
Cocconeis placentula	..	..	..	..	..	140
Cymbella affinis	..	52	..	114	..	..
C. minuta	..	..	..	..	16	29
C. minuta var. silesiaca	..	..	..	..	..	141
C. sinuata	..	45	87	146	..	12
Diatoma vulgare	..	270	..	..	18	654
Fragilaria vaucheriae	..	..	..	..	..	70
Epithemia sorex	..	60	742	297	..	1,848
Gomphonema olivaceum	..	217	19	58	90	77
Navicula arvensis	..	..	..	..	12	..
N. cryptocephala	..	907	373	111	63	45
N. cryptocephala var. veneta	..	..	..	..	..	74
N. pelliculosa	..	..	..	..	37	..
N. salinarum var. intermedia	..	89	15	106	11	..
N. tripunctata	..	217	219	31	20	19
N. viridula	..	..	..	..	..	272
N. viridula var. avenacea	..	..	..	..	..	125
Nitzschia chasei	..	142	98	..	..	..
N. dissipata	..	232	94	160	..	70
N. fonticola	..	..	..	..	50	..
N. frustulum	..	157	117	195	..	132
N. holsatica	..	352	..	50	29	12

Table 4-17. (Continued)

STATION/Taxa	Date	Density (Units/mm^2) 1974	1975	1976	1978	1979	1980
STATION 27 - Continued							
	JULY - Continued						
Rhoicosphenia curvata		..	..	..	..	12	400
Synedra ulna		..	502	..	8	77	101
Calothrix spp.		..	30	3,241	2,994	14	..
Lyngbya spp.		..	2,208	..	1,385	332	..
Unidentified pennate diatoms		..	..	..	..	..	97
Cladophora glomerata		..	..	..	..	..	1,825
Audouinella violacea		..	..	..	..	..	193
	AUGUST						
Achnanthes minutissima		..	..	..	..	..	876
A. spp.		..	..	102	10	..	..
Amphora ovalis var. pediculus		..	2,543	425	14	..	..
A. perpusilla		..	..	..	..	492	6
Cocconeis pediculus		..	..	589	26	..	10
C. placentula		..	315	..	16	13	88
Cymbella minuta var. silesiaca		..	..	..	..	..	268
Diatoma vulgare		..	765	..	..	..	44
Epithemia sorex		..	3,774	1,796	334	152	2,049
Gomphonema intricatum		..	..	255	3	..	..
G. olivaceum		..	..	..	..	..	122
G. ventricosa		..	1,148	..	..	..	
Navicula cryptocephala		..	2,183	346	7	..	11
N. notha		..	..	181	..	15	65
N. salinarum var. intermedia		..	1,328	..	3	..	..
N. tripunctata		..	..	..	..	..	79
N. viridula		..	..	..	..	..	107
N. viridula var. avenacea		..	..	..	..	..	237
Nitzschia chasei		..	878	..	..	..	..
N. dissipata		..	2,700	..	..	118	92
N. frustulum		..	2,115	108	12	..	128
N. holsatica		..	..	91	2	..	..
N. spp.		..	..	..	..	40	7
Rhiocosphenia curvata		..	..	..	..	..	243
Unidentified pennate diatoms		..	..	..	..	30	..
Cladophora glomerata		..	..	..	..	..	268
C. sp.		..	..	..	..	..	757
Phormidium sp.		..	..	..	..	..	166

Table 4-17. (Continued)

STATION/Taxa Date	Density (Units/mm^2) 1974	1975	1976	1978	1979	1980
STATION 27 - Continued						
OCTOBER - Continued						
Calothrix spp.	1,103	124	..	..	141	..
Lyngbya spp.	596	1,317	..	..	192	..
Phormidium spp.	..	..	..	..	39	56
Cladophora glomerata	..	..	..	..	..	255
Anabaena sp.	..	..	..	..	..	64
Phormidium sp.	..	..	..	..	..	56
STATION 29						
APRIL						
Achnanthes lanceolata	..	..	..	..	3	15
A. minutissima	..	..	..	..	..	168
A. spp.	..	731	38	22	104	..
Amphora ovalis var. pediculus	..	79	874	3	..	..
A. perpusilla	..	..	..	..	3	21
Cocconeis placentula	..	..	..	..	2	43
Cymbella sinuata	..	..	180	..	..	64
Epithemia sorex	..	1,192	117	..	..	283
Fragilaria vaucheriae	..	..	..	..	5	11
Gomphonema olivaceum	..	574	1,115	1,768	15	137
Navicula cryptocephala	..	889	540	545	2	48
N. pelliculosa	..	34	82	1,977	28	4
N. tripunctata	..	292	204	78	..	1
N. viridula	..	1,204	2,737	560	13	380
Nitzschia dissipata	..	1,474	986	590	..	253
N. fonticola	..	..	..	..	3	27
N. frustulum	..	101	187	103	..	3
N. palea	..	123	243	4	..	43
N. sp.	..	..	..	..	..	27
Surirella ovata	..	..	..	..	..	13
Calothrix spp.	..	979	7	..	..	..
Lyngbya spp.	..	259	..	..	..	..
Plectonema spp.	..	250	..	..	..	..

Table 4-17. (Continued)

STATION/Taxa Date	Density (Units/mm^2) 1974	1975	1976	1978	1979	1980
STATION 27 - Continued						
AUGUST - Continued						
Calothrix spp.	..	68	2,692	1,194	74	418
Lyngbya spp.	..	697	..	49	152	..
Tolypothrix sp.	..	..	..	..	..	106
Audouinella violacea	..	..	..	..	..	149
OCTOBER						
Achnanthes spp.	34	169	..	62	91	..
Amphora ovalis var. pediculus	23	495	..	6	..	..
A. perpusilla	..	..	..	..	20	1
Cocconeis pediculus	168	23	..	16	20	113
C. placentula	..	..	..	..	21	6
Cymbella affinis	..	..	..	..	15	..
C. minuta var. silesiaca	..	..	..	..	..	74
C. sinuata	..	..	..	15	..	..
Diatoma vulgare	..	..	..	..	..	62
Epithemia sorex	5,411	7,594	..	..	460	1,590
Gomphonema intricatum	22	113	..	24	..	..
G. olivaceum	259	79	..	46	..	64
G. tenellum	..	..	..	..	30	..
Navicula cryptocephala	259	1,969	..	..	17	..
N. cryptocephala var. veneta	..	..	..	..	..	34
N. pelliculosa	..	..	..	23	..	..
N. salinarum var. intermedia	315	776	..	..	67	..
N. secreta var. apiculata	..	..	..	..	..	32
N. tripunctata	113	787	..	..	21	63
N. viridula var. avenacea	..	..	..	..	..	90
Nitzschia chasei	..	405	..	..	..	..
N. dissipata	146	2,025	..	6	..	101
N. fonticola	..	..	..	..	17	..
N. frustulum	90	450	..	6	..	31
N. holsatica	..	..	..	8	..	32
N. linearis	..	..	..	..	..	71
N. palea	..	..	..	..	..	68
N. spp.	..	..	..	..	87	32
Rhoicosphenia curvata	..	..	..	..	60	139
Surirella ovata	..	810	..	..	..	..
Unidentified pennate diatoms	..	..	..	..	30	3

Table 4-17. (Continued)

STATION/Taxa Date	Density (Units/mm^2) 1974	1975	1976	1978	1979	1980
STATION 29 - Continued						
MAY [1]						
Achnanthes minutissima	..	..	..	..	0 [1]	16
Amphora perpusilla	..	..	..	..	..	45
Cocconeis placentula	..	..	..	..	..	2
Cymbella sinuata	..	..	..	..	..	10
Fragilaria vaucheriae	..	..	..	..	..	1
Gomphonema olivaceum	..	..	..	..	..	14
Navicula cryptocephala	..	..	..	..	..	2
N. notha	..	..	..	..	..	2
N. secreta var. apiculata	..	..	..	..	..	6
N. viridula	..	..	..	..	..	3
Nitzschia frustulum	..	..	..	..	..	3
Rhoicosphenia curvata	..	..	..	..	..	2
Phormidium sp.	..	..	..	..	..	1
JUNE						
Achnanthes spp.	..	27	408	0 [1]	0 [1]	0 [1]
Amphora ovalis var. pediculus	..	400	487	..	..	..
Biocoeca lacustris	..	..	669	..	..	..
Calothrix spp.	..	36	4,579	..	..	..
Cyclotella meneghiniana	..	40	..	..	..	..
Cymbella sinuata	..	166	181	..	..	..
Gomphenema olivaceum	..	9	782	..	..	..
Lyngbya spp.	..	36	..	..	..	..
Navicula cryptocephala	..	128	1,122	..	..	..
N. pelliculosa	..	61	317	..	..	..
N. tripunctata	..	32	295	..	..	..
Nitzschia dissipata	..	29	816	..	..	..
N. frustulum	..	488	2,312	..	..	..

Table 4-17. (Continued)

STATION/Taxa	Date	Density (Units/mm^2) 1974	1975	1976	1978	1979	1980
STATION 29 - Continued							
	JULY						
Achnanthes minutissima		..	135	45	6	8	392
Amphora ovalis var. pediculus		..	2,129	306	6	..	..
A. perpusilla		..	..	..	..	44	91
Bicoeca lacustris		..	120	..	18	..	..
Cocconeis pediculus		..	..	329	..	..	..
C. placentula		..	..	91	22	..	51
Cyclotella meneghiniana		..	..	..	..	3	67
Cymbella minuta		..	..	..	..	5	113
C. minuta var. silesiaca		..	..	..	..	..	129
C. sinuata		..	307	170	8	5	6
Diatoma vulgare		..	..	..	..	..	264
Epithemia sorex		..	127	5,315	3	..	1,961
Fragilaria vaucheriae		..	143	11	..	4	8
Gomphonema intricatum		..	82	283	..	..	8
G. olivaceum		..	420	34	17	21	140
Navicula cryptocephala		..	398	328	2	22	26
N. pelliculosa		..	..	..	..	7	..
N. tripunctata		..	22	79	..	4	18
N. viridula		..	..	..	..	5	25
N. viridula var. avenacea		..	..	..	..	..	129
Nitzschia dissipata		..	306	11	3	..	139
N. fonticola		..	..	..	..	12	..
N. frustulum		..	135	79	22	..	631
N. holsatica		..	239	..	1	17	..
N. spp.		..	..	..	..	..	..
Rhiocosphenia curvata		..	..	..	..	..	198
Synedra ulna		..	..	..	..	..	30
Calothrix spp.		..	52	2,709	58	..	..
Lyngbya spp.		..	5,160	..	80	75	..
Phormidium spp.		..	..	..	..	22	88
Cladophora spp.		..	1	33	26	..	..
C. glomerata		..	..	..	..	..	1,008
Stigeoclonium tenue		..	..	..	..	..	714
Audouinella violacea		..	..	..	..	..	722

Table 4-17. (Continued)

STATION/Taxa	Date	Density (Units/mm^2) 1974	1975	1976	1978	1979	1980
STATION 29 - Continued							
	AUGUST						
Achnanthes minutissima		..	..	..	..	..	3,939
A. spp.		..	7	67	69	12	..
Amphora ovalis var. pediculus		..	120	33	11	..	..
A. perpusilla		..	..	..	..	21	186
Cocconeis pediculus		..	..	707	73	..	25
C. placentula		..	34	115	49	70	50
Cyclotella meneghiniana		..	..	133	..	10	206
Cymbella affinis		..	105	23	6	..	..
C. minuta		..	..	..	..	..	144
C. minuta silesiaca		..	..	..	..	..	587
C. sinuata		..	..	..	..	6	..
Epithemia sorex		..	3,747	2,517	864	54	784
Gomphonema olivaceum		..	79	13	22	21	94
G. intricatum		..	..	622	..	..	..
G. ventricosa		..	94	..	..	..	..
Navicula cryptocephala		..	476	140	28	..	12
N. salinarum var. intermedia		..	712	125	6	..	..
N. tripunctata		..	128	214	..	..	121
N. viridula var. avenacea		..	..	..	..	..	179
Nitzschia dissipata		..	739	84	..	..	456
N. fonticola		..	..	..	..	20	..
N. frustulum		..	409	172	23	..	934
N. spp.		..	..	..	..	6	16
Rhoicosphenia curvata		..	..	..	..	3	680
Calothrix spp.		..	75	2,083	890	11	83
Lyngbya spp.		..	795	6	30	3	250
Cladophora glomerata		..	..	..	..	..	222
C. spp.		..	..	41	90	..	..
Tolypothrix sp.		..	..	..	..	..	290
Audouinella violacea		..	..	..	..	..	231

Table 4-17. (Continued)

STATION/Taxa Date	Density (Units/mm^2) 1974	1975	1976	1978	1979	1980
STATION 29 - Continued						
OCTOBER						
Achnanthes spp.	956	197	..	197	185	..
Amphora ovalis var. pediculus	11	2,043	..	2	..	..
A. perpusilla	..	..	..	..	13	..
Cocconeis pediculus	90	..	..	2	..	172
C. placentula	..	..	..	9	27	10
Cymbella affinis	371	57	..	..	22	..
C. minuta var. silesiaca	..	..	..	..	..	1,434
C. sinuata	..	338	..	10	35	..
Diatoma vulgare	..	..	..	..	..	91
Epithemia sorex	2,486	13,231	..	18	194	151
Gomphonema intricatum	..	6	..	152	55	..
G. olivaceum	158	113	..	24	..	75
Navicula cryptocephala	889	807	..	4	11	12
N. pelliculosa	..	..	..	73	20	..
N. salinarum var. intermedia	338	452	..	1	..	5
N. tripunctata	102	198	..	..	14	60
N. viridula var. avenacea	..	..	..	..	..	192
Nitzschia dissipata	371	1,146	..	8	..	12
N. fonticola	..	..	..	..	35	3
N. frustulum	382	587	..	23	..	324
N. holsatica	45	34	..	18	..	..
N. palea	113	28	..	..	..	..
N. spp.	..	..	..	..	114	22
Rhoicosphenia curvata	..	..	..	..	29	340
Unidentified pennate diatoms	..	..	..	..	22	8
Lyngbya spp.	1,170	1,962	..	13	53	..
Oscillatoria spp.	799	96	..	..	..	..
Mougeotia spp.	..	..	..	..	..	12
Cladophora glomerata	..	..	..	..	..	934
Lemanea fucina	..	..	..	..	..	999

1/ May was not sampled prior to 1979

of species diversity and mean biomass for periphyton samples collected during baseline and MDP studies is provided in Tables 4-18 and 4-19, respectively.

Much variation in periphyton parameters exists for samples collected at each station during a particular month for different years. Periphyton community structure is influenced by factors such as light, temperature, current velocity, substrate and turbidity which vary both seasonally and annually. Since annual variation may generate a completely new set of environmental conditions for a particular station during a particular month from year to year, substantial annual fluctuations in periphyton community structure may be evident. For instance, spring runoff and summer warming may occur at different times each year resulting in a completely different set of dominant periphyton species for the initial periphyton sample collected each year. While data obtained for a particular year compared with the data of previous years may provide some indication of general changes in periphyton community structure within the study area, evaluation of seasonal variations may be more appropriate to determining the effect of environmental changes on the periphyton. This concept is emphasized in the discussion of the 1980 data collected at each station.

The 1980 periphyton data were generally characterized by greater densities and diversities compared to the 1979 data which were lower than the values of previous years. However, at Station 13 where mine dewatering activities exerted the greatest influence, 1980 densities and biomass determinations were lower than in 1979. Biomass values for 1980 at Station 20 and 21 were lower than in 1979 but biomass at Stations 27 and 29 was higher than in 1979. Excluding 1976 data, which exhibited great fluctuations, the general trend in periphyton densities was a decrease from high levels in early spring to lower values in May and June presumably due to the effects of runoff. A relatively steady increase in densities was evident in summer and fall.

The dominant diatom genus present in the periphyton of baseline and monitoring samples collected at Station 13 was Achnanthes spp. (primarily Achnanthes minutissima and Achnanthes affinis). Taxa dominant at this station only during MDP studies were the blue-green algae, Phormidium spp., in April and

Table 4-18. Comparison of Diversity Indices of Periphyton During RBOSC MDP Studies (1978, 1979 and 1980) and RBOSC Aquatic Baseline Studies (1974-1976)

			Baseline			MDP		
Location	Month	Index	1974	1975	1976	1978	1979	1980
Station 13	April	Shannon	..	1.57	2.24	2.77	1.03	2.59
		Evenness	..	0.40	0.52	0.71	0.33	0.68
		No. of Species	..	15	20	14	23	44
	May	Shannon					1.06	2.50
		Evenness					0.334	.76
		No. of Species					24	27
	June	Shannon	..	2.55	1.92	1.94	1.80	1.57
		Evenness	..	0.76	0.58	0.70	0.57	0.51
		No. of Species	..	10	10	7	23	21
	July	Shannon	..	2.73	2.93	..	0.21	2.22
		Evenness	..	0.66	0.67	..	0.82	0.60
		No. of Species	..	18	21		13	40
	August	Shannon	..	1.17	1.37	1.70	0.33	1.76
		Evenness	..	0.29	0.33	0.49	0.15	0.50
		No. of Species	..	17	17	12	9	34
	October	Shannon	2.49	2.66	..	2.77	0.20	1.45
		Evenness	0.58	0.61	..	0.67	0.09	0.48
		No. of Species	19	21	..	17	10	20
Station 14	April	Shannon	..	2.41	2.43	2.44	1.47	1.38
		Evenness	..	0.56	0.54	0.63	0.42	0.421
		No. of Species	..	..	23	15	32	25
	May	Shannon					1.26	1.93
		Evenness					0.397	0.527
		No. of Species					24	39
	June	Shannon	..	2.05	1.36	..	2.42	2.12
		Evenness	..	0.47	0.34	..	0.63	0.59
		No. of Species	..	21	16	..	45	36
	July	Shannon	..	2.73	2.93	..	2.11	2.84
		Evenness	..	0.66	0.67	..	0.58	0.72
		No. of Species	..	18	21	..	38	51

Table 4-18. (Continued)

Location	Month	Index	Baseline 1974	Baseline 1975	Baseline 1976	MDP 1978	MDP 1979	MDP 1980
Station 14 (Continued)	August	Shannon	..	1.78	3.36	1.79	2.31	2.22
		Evenness	..	0.44	0.69	0.63	0.65	0.62
		No. of Species	..	16	29	7	35	36
	October	Shannon	1.37	1.55	..	2.58	2.01	1.16
		Evenness	0.45	0.43	..	0.73	0.58	0.37
		No. of Species	9	12	..	12	32	23
Station 20	April	Shannon	..	1.74	2.17	1.22	1.92	2.52
		Evenness	..	0.46	0.58	0.36	0.57	0.67
		No. of Species	..	13	15	11	29	42
	May	Shannon					1.54	2.23
		Evenness					0.444	0.62
		No. of Species					32	37
	June	Shannon	..	0.58	1.98	1.47	1.63	1.94
		Evenness	..	0.17	0.56	0.46	0.48	0.57
		No. of Species	..	12	12	10	31	30
	July	Shannon	..	3.48	2.70	0.74	1.50	1.686
		Evenness	..	0.76	0.64	0.27	0.43	0.501
		No. of Species	..	24	19	7	33	29
	August	Shannon	..	1.04	2.31	0.78	2.06	0.99
		Evenness	..	0.29	0.52	0.24	0.53	0.29
		No. of Species	..	12	21	9	50	29
	October	Shannon	1.77	1.28	..	3.25	0.65	1.05
		Evenness	0.51	0.34	..	0.76	0.22	0.34
		No. of Species	11	13	..	18	19	22
Station 21	April	Shannon	..	..	..	..	2.40	1.68
		Evenness	..	..	..	..	0.64	0.46
		No. of Species	..	..	..	..	42	39
	May	Shannon					1.48	1.92
		Evenness					0.450	51
		No. of Species					27	44

Table 4-18. (Continued)

Location	Month	Index	Baseline 1974	Baseline 1975	Baseline 1976	MDP 1978	MDP 1979	MDP 1980
Station 21 (Continued)	June	Shannon	..	1.57	2.59	1.81	1.63	1.64
		Evenness	..	0.44	0.64	0.48	0.46	0.49
		No. of Species	..	12	17	14	34	29
	July	Shannon	..	2.90	2.60	0.58	1.44	1.46
		Evenness	..	0.72	0.58	0.19	0.43	0.45
		No. of Species	..	17	23	9	28	25
	August	Shannon	..	2.04	1.97	0.72	1.71	1.27
		Evenness	..	0.51	0.54	1.43	0.53	0.37
		No. of Species	..	11	13	12	26	31
	October	Shannon	1.45	0.48	..	3.12	0.65	1.27
		Evenness	0.44	0.14	..	0.78	0.24	0.36
		No. of Species	10	10	..	16	15	32
Station 27	April	Shannon	..	1.47	2.36	0.93	2.36	1.78
		Evenness	..	0.42	0.60	0.27	0.67	0.50
		No. of Species	..	12	16	11	34	35
	May	Shannon					..	2.4
		Evenness					..	.58
		No. of Species					..	60
	June	Shannon	..	2.48	3.32	..	..	..
		Evenness	..	0.65	0.74	..	..	..
		No. of Species	..	14	23	..	..	..
	July	Shannon	..	3.44	1.89	2.52	2.64	2.46
		Evenness	..	0.73	0.49	0.57	0.65	0.63
		No. of Species	..	26	15	22	59	49
	August	Shannon	..	3.38	2.82	1.37	2.05	2.66
		Evenness	..	0.66	0.63	0.42	0.58	0.685
		No. of Species	..	34	23	10	35	49
	October	Shannon	1.87	2.89	..	2.99	2.44	2.32
		Evenness	0.44	0.61	..	0.79	0.68	0.58
		No. of Species	18	26	..	14	36	52

Table 4-18. (Continued)

Location	Month	Index	Baseline 1974	Baseline 1975	Baseline 1976	MDP 1978	MDP 1979	MDP 1980
Station 29	April	Shannon	..	3.25	2.77	2.09	1.77	2.48
		Evenness	..	0.69	0.63	0.61	0.51	0.65
		No. of Species	..	27	21	11	32	44
	May	Shannon					..	2.28
		Evenness					..	.58
		No. of Species					..	49
	June	Shannon	..	2.80	3.06	..	..	..
		Evenness	..	0.67	0.69	..	..	..
		No. of Species	..	19	21	..	..	..
	July	Shannon	..	2.72	2.05	2.91	2.67	2.57
		Evenness	..	0.57	0.52	0.74	0.71	0.69
		No. of Species	..	26	16	16	43	41
	August	Shannon	..	2.44	3.09	2.20	2.35	2.51
		Evenness	..	0.51	0.64	0.57	0.66	0.64
		No. of Species	..	27	28	16	35	49
	October	Shannon	..	2.65	2.17	2.39	2.61	2.03
		Evenness	..	0.61	0.47	0.62	0.72	
		No. of Species	..	20	24	15	38	39

Table 4-19. Mean Periphyton Biomass (Ash-Free Dry Weight) During RBOSC MDP Studies (1978, 1979 and 1980) and RBOSC Aquatic Baseline Studies (1974-1976)

Station	Month	Biomass (mg/cm^2)				
		1975	1976	1978	1979	1980
13	April	1.018	2.594	0.696	1.737	1.340
	May	...	...	...	0.585	0.238
	June	0.726	0.260	0.588	0.801	0.510
	July	2.522	1.708	...	0.571	0.316
	August	1.032	0.974	0.688	0.414	0.570
	October	2.954	2.354	2.818	1.204	0.438
14	April	27.182	1.234	2.940	0.992	5.413
	May	...	...	...	1.337	1.150
	June	1.210	0.712	...	2.383	0.627
	July	12.566	0.644	...	0.989	0.517
	August	1.086	0.830	2.276	1.547	2.408
	October	0.470	0.462	1.481	2.614	1.478
20	April	1.484	0.846	1.572	0.783	1.108
	May	...	...	...	0.598	0.793
	June	0.572	2.272	2.222	1.997	1.609
	July	0.816	1.632	3.294	0.285	2.402
	August	0.704	4.854	2.162	0.865	2.175
	October	3.367	0.926	2.094	0.397	12.794
21	April	2.136	0.754	6.008	1.641	1.522
	May	...	...	...	1.016	0.262
	June	9.390	6.494	1.922	1.960	2.189
	July	0.910	7.710	6.578	2.734	0.736
	August	0.896	2.356	5.044	0.841	5.904
	October	3.628	1.078	6.988	0.571	3.950
27	April	8.862	6.486	1.040	2.465	11.898
	May	...	...	...	...	0.917
	June	1.040	1.358	...	...	...
	July	19.218	4.786	1.602	1.507	3.799
	August	7.874	7.874	3.728	2.575	7.860
	October	15.382	9.460	0.148	6.545	7.214
29	April	6.936	2.330	1.124	0.694	3.158
	May	...	...	...	...	1.192
	June	3.250	2.720	...	...	...
	July	12.396	9.158	0.364	0.722	2.151
	August	6.794	11.388	1.860	0.971	11.250
	October	9.502	7.494	0.312	10.243	15.312

May 1979 and 1980, and Calothrix spp. in July 1978; as well as, the green algae, Cladophora sp., Microspora sp., Spirogyra sp., and Zygnema sp., in August 1980, and the chantransia-phase of the red alga, Batrachospermum sp., in October 1980. Batrachospermum is generally indifferent to water chemistry, requires a swift current (Hynes 1970) and has been associated with springs and spring-fed streams (Ward and Dufford 1979). The Shannon-Weiner diversity indices for 1980 were higher than in 1979 and were more similar to the values obtained during baseline and 1978 monitoring studies. The 1980 biomass values at Station 13 were the lowest recorded during the RBOSC aquatic sampling program, possibly due to the scouring effect of the discharge from Tract C-a.

At Station 14, total periphyton densities exhibited wide seasonal and annual variations. The habitat at this station was pond-like with limited rock substrate. Occasional disturbance by livestock and farm machinery made it difficult to assess changes and impacts. Furthermore, a portion of the earthen dam was washed out during late winter 1980 and then the habitat changed from pond-like to a stream habitat during the following April and May. The dam was not reconstructed until June 1980. No trends in total periphyton densities were apparent. During the 1980 monitoring studies, dominant periphyton taxa included Achnanthes spp., Cyclotella meneghiniana, Fragilaria vaucheriae, Fragilaria crotonensis and Navicula secreta var. apiculata. With the exception of Fragilaria crotonensis, these taxa have generally been found in all samples collected at this station during baseline and monitoring studies.

At the Yellow Creek Stations 20 and 21, total periphyton densities were higher in 1980 than in 1979. Lowest values for both stations occurred in the spring, while highest densities were present in July 1980. Monthly changes in diversity at these stations also exhibited similar patterns from year to year. Comparison of monitoring and baseline diversity data showed no obvious differences or trends. Although the 1980 periphyton biomass was generally higher than in 1979, it was similar to values recorded in previous years.

A sulfur bacterium was numerous in the spring and fall samples collected at Stations 20 and 21. The size and shape of this organism is very similar to

the diatom, Navicula pelliculosa. A check of the periphyton voucher collection from previous years revealed that the large numbers of Navicula pelliculosa recorded were actually this bacterium. Therefore, for comparison purposes, it's density was included in the total densities for each station.

Spring 1980 periphyton communities at Station 20 were dominated by Navicula pelliculosa, Achnanthes spp., Fragilaria vaucheriae and Surirella ovata. The latter is reported to have its best development during low water temperatures and usually has its maximum growth in the spring (Round 1973). July communities were dominated by an immature green alga, Bulbochaetae sp., as well as by Achnanthes spp. and Cyclotella meneghiniana. By August, Bulbochaetae sp. had become less abundant while Achnanthes affinis, Cyclotella meneghiniana and Synedra pulchella var. lanceolata were most numerous. Bulbochaetae sp., Achnanthes spp. and Cyclotella meneghiniana dominated the fall periphyton. The 1978 spring periphyton assemblage was similar to the one observed in 1980. However, the 1978 summer community was dominated by the blue-green alga, Calothrix spp., which was the major constituent for a three month period. The 1979 periphyton composition was similar to the assemblage recorded for 1980.

At Station 21, the 1980 periphyton was somewhat similar to the composition found at Station 20. The spring community was comprised of Surirella ovata and Fragilaria vaucheriae, the summer assemblage was dominated by Bulbochaetae sp., and fall periphyton was dominated by Achnanthes affinis. The green alga, Enteromorpha sp., was found during October 1980, as was the aquatic vascular plant, Zannichella palustris. Results of the 1978 and 1979 monitoring studies at Station 21 were similar to the results obtained at Station 20.

When comparing the periphyton sampled at Stations 20 and 21 during baseline studies to that sampled during MDP studies, it becomes apparent that in both cases the spring and fall communities seem to be dominated by a group of diatoms whose relative abundance varies annually. In addition, the summer trend of dominance by green algae has increased during monitoring studies from 1978 through 1980.

Periphyton was not collected at Stations 27 and 29 on the White River during June 1980 as a result of high water conditions. During the other sampling periods in 1980, densities at these stations were the highest recorded since the initiation of monitoring studies, with the exception of the data for both stations in April 1980 which were higher in 1979 but lower in 1978. During 1980, total densities were higher at the upstream station than at the downstream station in the spring, but lower in summer and fall.

At the upstream Station 27, the spring 1980 periphyton was comprised primarily of Epithemia sorex, Navicula cryptocephala, Navicula viridula, and Nitzschia dissipata. The summer assemblage was dominated by Cladophora glomerata, Diatoma vulgare, Epithemia sorex and Rhoicosphenia curvata. The red alga, Audouinella violaceae, was present as an epiphyte on Cladophora glomerata. Dominant fall periphyton species were Cladophora glomerata, Epithemia sorex, Cocconeis pediculus and Rhoicosphenia curvata. Seasonal trends in the diatom flora were somewhat similar to patterns seen in previous years.

A notable change in the composition of the 1980 periphyton communities at Station 27 in comparison to previous years was the dominance of the green alga, Cladophora glomerata, during summer and fall. In addition, community composition observed during the spring for the baseline studies varied from assemblages found during monitoring studies. The 1980 Shannon-Weiner diversities at Station 27 were similar to 1978 and 1979 values. Comparison of MDP and baseline diversities indicate similar results which appear, however, one month out of phase. This phenomenon is probably due to annual fluctuation in the extent and timing of spring runoff. Biomass determinations for 1980 at Station 27 were higher than in 1978 or 1979, but lower than or approximately the same as baseline values.

At the White River Station 29, downstream from the confluence with Yellow Creek, 1980 periphyton composition differed slightly from the assemblage found at Station 27. The spring community was dominated by Epithemia sorex, Navicula viridula and Nitzschia dissipata. In the summer, Achnanthes minutissima,

Epithemia sorex, Nitzschia dissipata, Nitzschia frustulum, Cladophora glomerata, Stigeoclonium tenue, Audouinella violaceae and Tolypothrix sp. were the most numerous flora at this station. By October 1980, the dominant periphyton taxa were Cymbella minuta var. silesiaca, Navicula viridula, Rhoicosphenia curvata, Lemanea fucina and Cladophora glomerata. As with Station 27, the 1980 data for Station 29 were similar to the data recorded in previous years with a few notable differences. In 1980, Stigeoclonium tenue, Audouinella violaceae and Lemanea fucina were recorded for the first time as dominant forms. The Shannon-Weiner diversity indices were similar in 1978, 1979 and 1980. As with the upstream White River station, diversity determinations recorded during MDP studies seemed to be approximately a month or more out of phase with values recorded during baseline studies.

Periphyton biomass was higher in 1980 than in 1978 and 1979. Biomass at Station 29 was higher in April and July 1980, but lower in August and October 1980 than at Station 27. During the 1978 and 1979 monitoring studies, biomass at the downstream station was generally lower than at the upstream station. Differences in biomass at these two stations were less obvious during baseline studies.

In summary, changes may have occurred in the periphyton communities since the initiation of baseline studies which cannot be explained as seasonal variations. Also, changes in physical parameters such as temperature and current velocity are not consistent with changes observed in the structure of periphyton communities. At Station 13, the 1980 densities and biomass decreased, and as in 1979, blue-green algae dominated the spring community. At Stations 20 and 21, densities and biomass increased in 1980 compared to 1979, but both parameters were similar to the data from previous years. The green alga, Bulbochaetae sp., displayed increasing dominance in the periphyton communities at Stations 20 and 21 during the summers of 1979 and 1980. At Stations 27 and 29, biomass and density values increased in 1980. Cladophora glomerata became the dominant algae at both stations in 1980.

Generally, the stations with high conductivity readings (Stations 13, 14, 20 and 21) showed species combinations more attuned to higher osmotic levels. The

communities found at the stations having less saline water (Stations 27 and 29) were comprised of taxa such as Epithemia sorex, Gomphonema olivaceum and Nitzschia dissipata which are more common in low salinity, but relatively hard, water (Lowe 1974).

Changes noted at Station 13 may have been due in part to an increase in flow with a concomitant increase in turbidity resulting from dewatering activities. The strength of the current is one of the most important factors influencing the kinds of species present in a stream (Patrick 1977). Also, some blue-green algae have been shown to be favored by increasing turbidity (Hutchinson 1976).

It is difficult to assess whether the changes which have occurred at Stations 14, 20, 21 and 29 are due to Tract C-a project activities or to natural variation in environmental conditions. The latter is probably the major cause because surface flow originating in the area of the tract disappears into the alluvium a short distance downstream from Station 14 and hydrologic tests have shown that Tract C-a surface waters may not reach lower Yellow Creek or the White River (Section 5.0 Hydrology). Another strong argument in favor of natural variation is that Station 27 on the White River, upstream from any project influence, has shown similar changes in periphyton density, biomass and species diversity as has Station 29 which is downstream on the White River from the confluence of Yellow Creek.

B. Benthos

1. Objectives and Rationale

Benthic macroinvertebrates constitute the major component of the secondary trophic level in aquatic ecosystems on and near Tract C-a. Their limited mobility and well-documented susceptibility to physical and chemical changes in their environment make them an important element of the MDP Monitoring Program (Kolkowitz and Marsson 1909; Hynes 1960,; Tarzwell 1965; Cairns and Dickson 1973; Hart and Fuller 1974; Hilsenhoff 1977; Beck 1977; Hubbard and Peters 1978; Harris and Lawrence 1978; Surdick and Gaufin 1978). Data collected on benthos species composition, relative abundance and diversity at all sampling

stations permits the evaluation of the effects of development activity on benthos, as well as identification of potential impacts on other components of the aquatic system.

2. Methods

Methods used for the benthos sampling program were described in RBOSC MDP Report 4 and are not repeated herein.

3. Results and Discussion

A total of 60 taxa was identified from macroinvertebrate samples collected during the 1980 monitoring studies. The distribution of taxa among stations by sampling dates is provided in Appendix 4-2.6. The seasonal changes in species occurrence at each station are shown in Appendix 4-2.7. Macroinvertebrate enumeration data by sample date for the 1980 monitoring program are presented in Appendix 4-2.8. Density and species diversity calculations for all sites by sampling date are provided in Appendix 4-2.9.

The mean densities of the major macroinvertebrate taxa collected during RBOSC baseline studies (1974-1976) and MDP monitoring studies (1978-1980) are presented in Table 4-20. Data are organized by station and sampling date.

Comparison of species diversity indices from baseline and MDP studies are provided in Table 4-21. A discussion of the 1980 results by sampling station is included in this section.

In 1980, the density of macroinvertebrates at Station 13 on Corral Gulch directly below the MIS facilities was consistently higher than during the same periods in 1979 (with the exception of the June sampling date). In April, May and June 1980, Chironomidae was the most abundant taxon. In July, the tremendous increase in numbers was due to Simuliidae (black flies). Ephemeroptera (*Baetis* sp.) was found in all months except April and comprised 25 percent of the total fauna in August and October. Very few Simuliidae were found in April and October. Other Dipterans (Muscidae) and Oligochaeta were abundant in October 1980.

Table 4-20. Major Benthic Macroinvertebrate Taxa Observed During RBOSC MDP Studies (1978-1979) and RBOSC Aquatic Baseline Studies (1974-1976).

STATION/Taxa	Date	Mean Density (Units/m^2) 1974	1975	1976	1978	1979	1980
STATION 13	APRIL						
Nematoda		..	241	24	42	6	0
Oligochaeta		..	18,190	18	150	42	45
Ephemeroptera		..	2,688	139	..	..	..
Plecoptera		..	91	24	..	..	..
Coleoptera		..	..	..	6	..	7
Diptera		..	476	24	12	6	..
Chironomidae		..	10,896	1,961	66	30	1,372
	MAY [1/]						
Oligochaeta		..	..	..	..	78	7
Ephemeroptera		..	..	..	..	12	13
Chironomidae		..	..	..	..	..	19
	JUNE						
Ephemeroptera		..	..	..	..	..	26
Nematoda		..	36	..	6	0	..
Oligochaeta		..	48	..	18	163	13
Coleoptera		..	..	..	..	..	7
Diptera		..	78	272	12	6	..
Chironomidae		..	12	153	6	12	32
	JULY						
Nematoda		..	..	30	..	..	..
Oligochaeta		..	30	109	6	283	110
Ephemeroptera		..	54	422	..	..	524
Plecoptera		..	..	60	..	..	..
Diptera		..	24	222	6	12	4,816
Chironomidae		..	102	2,819	42	12	414

Table 4-20. (Continued)

STATION/Taxa	Date	Mean Density (Units/m^2) 1974	1975	1976	1978	1979	1980
STATION 13 - Continued							
	AUGUST						
Nematoda		..	42	48	..	6	..
Oligochaeta		..	..	935	54	638	45
Ephemeroptera		..	1,267	3,445	6	..	712
Plecoptera		..	935	404	..	..	13
Diptera		..	1,110	620	6	..	932
Chironomidae		.	1,507	2,697	36	30	893
	OCTOBER						
Nematoda		382	..	..	..	..	..
Oligochaeta		14,551	66	..	1,617	385	149
Ephemeroptera		5,358	66	..	12	126	129
Plecoptera		753	1,478	..	72	788	13
Diptera		7,063	416	..	6	150	162
Chironomidae		38,373	409	..	138	54	65
STATION 14							
	APRIL						
Nematoda		..	252	187	..	6	..
Oligochaeta		..	3,094	295	921	1,456	401
Ephemeroptera		..	1,199	36	..	18	91
Plecoptera		..	..	6	..	..	..
Coleoptera		..	..	42	126	..	..
Trichoptera		..	..	..	..	..	7
Diptera		..	666	235	66	30	809
Chironomidae		..	59,836	16,531	3,441	632	4,434

Table 4-20. (Continued)

STATION/Taxa	Date	Mean Density (Units/m^2) 1974	1975	1976	1978	1979	1980
STATION 14 - Continued							
	MAY [1/]						
Nematoda		..	..	..	..	66	13
Oligochaeta		..	..	..	..	6,438	401
Ephemeroptera		..	..	..	..	12	..
Coleoptera		..	..	..	..	..	13
Chironomidae		..	..	..	..	487	544
	JUNE						
Nematoda		..	119	458	150	12	7
Oligochaeta		..	30	241	1,356	3,664	317
Ephemeroptera		..	1,021	..	..	..	26
Coleoptera		..	15	284	..	48	..
Trichoptera		..	..	..	..	6	..
Diptera		..	770	3,723	2,219	66	214
Chironomidae		..	1,569	2,450	1,144	2,311	2,744
	JULY						
Nematoda		..	385	36	18	48	..
Oligochaeta		..	44	1,345	6,260	7,690	136
Ephemeroptera		..	30	6	60	78	..
Hemiptera		..	15	..	6	..	..
Coleoptera		..	252	779	132	..	7
Trichoptera		..	..	..	..	12	..
Diptera		..	385	1,394	1,146	896	615
Chironomidae		..	6,689	2,262	1,330	2,347	4,492

Table 4-20. (Continued)

STATION/Taxa	Date	Mean Density (Units/m^2) 1974	1975	1976	1978	1979	1980
STATION 14 - Continued							
	AUGUST						
Nematoda		..	74	6	..	78	7
Oligochaeta		..	444	826	3,379	10,909	570
Ephemeroptera		..	1,673	18	..	6	39
Plecoptera		..	..	..	..	..	..
Coleoptera		..	401	..	..	..	..
Hemiptera		..	..	12	..	..	..
Diptera		..	133	241	57	962	460
Chironomidae		..	29,084	452	226	8,141	977
	OCTOBER						
Nematoda		15	..	..	6	199	..
Oligochaeta		15	1,010	..	292	8,953	259
Ephemeroptera		2,486	118	..	..	48	19
Plecoptera		..	30	..	..	..	..
Coleoptera		..	44	..	6	..	..
Hemiptera		89	15	..	..	..	..
Diptera		311	162	..	58	2,046	221
Chironomidae		4,071	1,138	..	596	1,444	589
Amphipoda		..	29	..	13	..	..
STATION 20	APRIL						
Nematoda		..	145	253	289	..	..
Oligochaeta		..	884	2,341	222	12	..
Odonata		..	12	..	..	..	..
Diptera		..	4,157	97	3,156	84	13
Chironomidae		..	5,750	1,001	3,322	403	2,227

Table 4-20. (Continued)

STATION/Taxa	Date	Mean Density (Units/m^2) 1974	1975	1976	1978	1979	1980
STATION 20 - Continued							
	MAY [1/]						
Oligochaeta		..	..	..	..	12	26
Ephemeroptera		..	..	..	..	30	..
Coleoptera		..	..	..	..	6	19
Trichoptera		..	..	..	..	..	7
Chironomidae		..	..	..	..	1,943	181
	JUNE						
Nematoda		..	60	91	18	..	..
Oligochaeta		..	60	30	..	12	..
Ephemeroptera		..	..	..	..	30	..
Coleoptera		..	6	..	18	6	32
Diptera		..	489	2,370	2,930	511	1,534
Chironomidae		..	271	676	1,405	542	816
	JULY						
Nematoda		..	151	127	30	..	..
Oligochaeta		..	977	6	..	12	136
Ephemeroptera		..	..	18	..	..	..
Odonata		..	6	42	150	..	..
Coleoptera		..	24	133	60	6	7
Diptera		..	567	2,801	633	2,412	2,686
Chironomidae		..	54	1,725	974	289	..

Table 4-20. (Continued)

STATION/Taxa	Date	Mean Density (Units/m^2) 1974	1975	1976	1978	1979	1980
STATION 20 - Continued							
	AUGUST						
Nematoda		..	127	108	36	..	..
Oligochaeta		..	84	1,448	..	24	71
Ephemeroptera		..	36	24	699	..	39
Trichoptera		..	..	..	..	..	142
Odonata		..	..	24	66	..	..
Coleoptera		..	91	..	72	54	..
Diptera		..	181	4,730	2,321	18	453
Chironomidae		..	42	1,061	1,264	1,991	..
	OCTOBER						
Nematoda		..	833	..	6	..	..
Oligochaeta		63	1,955	..	42	72	..
Ephemeroptera		..	1,152	..	12	..	..
Odonata		25	36	..	6	..	..
Coleoptera		6	6	..	..	6	..
Trichoptera		..	..	..	..	18	162
Diptera		144	1,611	..	651	867	770
Chironomidae		1,127	409	..	1,893	2,004	19
STATION 21	APRIL						
Nematoda		..	66	290	114	..	..
Oligochaeta		..	12	271	295	6	..
Ephemeroptera		..	6	..	..	..	..
Odonata		..	..	..	..	..	..
Coleoptera		..	..	54	..	..	..
Diptera		..	1,623	338	4,515	54	26
Chironomidae		..	779	754	2,821	193	1,404

Table 4-20. (Continued)

STATION/Taxa	Date	Mean Density (Units/m^2) 1974	1975	1976	1978	1979	1980
STATION 21 - Continued							
	MAY [1/]						
Oligochaeta		..	..	..	..	54	45
Coleoptera		..	..	..	..	42	13
Trichoptera		..	..	..	..	..	7
Chironomidae		..	..	..	..	1,288	227
	JUNE						
Nematoda		..	24	356	162	..	..
Oligochaeta		..	247	332	54	..	13
Ephemeroptera		..	6	..	..	..	..
Odonata		..	..	6	..	..	..
Coleoptera		..	12	314	..	6	7
Diptera		..	3,197	537	1,998	367	1,761
Chironomidae		..	1,796	6,649	1,271	511	1,243
	JULY						
Nematoda		..	18	163	271	..	..
Oligochaeta		..	36	694	271	12	..
Ephemeroptera		..	..	91	96	..	..
Odonata		..	..	..	18	..	..
Coleoptera		..	12	561	42	24	..
Trichoptera		..	..	..	..	..	7
Diptera		..	688	374	898	2,316	731
Chironomidae		..	253	911	4,091	969	363

Table 4-20. (Continued)

STATION/Taxa	Date	Mean Density (Units/m^2) 1974	1975	1976	1978	1979	1980
STATION 21 - Continued							
	AUGUST						
Nematoda		..	6	36	301	..	..
Oligochaeta		..	..	2,654	186	132	13
Ephemeroptera		..	..	54	36	..	32
Odonata		..	30	12	6	..	19
Coleoptera		..	127	..	6	12	13
Trichoptera		..	..	..	..	..	45
Diptera		..	102	84	5,928	944	615
Chironomidae		..	235	84	1,246	1,769	201
	OCTOBER						
Nematoda		..	6	..	6	..	..
Oligochaeta		150	..	..	..	241	..
Ephemeroptera		19	66	..	12	..	19
Odonata		..	36	..	..	..	142
Coleoptera		..	6	..	6	6	71
Trichoptera		6	..	..	..	24	272
Diptera		417	874	..	2,253	1,270	401
Chironomidae		2,084	464	..	2,038	626	207
STATION 27	APRIL						
Oligochaeta		..	477	59	1,129	111	214
Ephemeroptera		..	280	1,698	2,527	513	278
Plecoptera		..	13	78	64	13	26
Odonata		..	..	..	..	6	..
Coleoptera		..	..	..	..	..	..
Trichoptera		..	13	85	233	..	65
Diptera		..	..	13	13	..	..
Chironomidae		..	516	555	608	13	13

Table 4-20. (Continued)

STATION/Taxa	Date	Mean Density (Units/m^2) 1974	1975	1976	1978	1979	1980
STATION 27 - Continued							
	JULY						
Oligochaeta		..	40	378	45	7	13
Ephemeroptera		..	..	2,835	433	1,157	757
Plecoptera		..	..	..	6	26	..
Coleoptera		..	..	..	..	20	..
Trichoptera		..	..	47	19	312	149
Diptera		..	34	93	96	40	26
Chironomidae		..	..	33	77	247	142
	AUGUST						
Oligochaeta		..	572	599	26	65	13
Ephemeroptera		..	151	1,238	1,390	5,751	1,793
Plecoptera		..	..	65	..	..	..
Odonata		..	..	..	..	13	7
Trichoptera		..	34	456	409	845	803
Diptera		..	13	72	214	13	78
Chironomidae		..	330	438	122	331	97
	OCTOBER						
Oligochaeta		250	644	..	52	1,267	252
Ephemeroptera		402	1,322	..	564	507	162
Plecoptera		38	143	..	12	39	7
Trichoptera		163	508	..	162	124	272
Diptera		6	46	..	13	26	20
Chironomidae		853	685	..	6	1,261	3,450

Table 4-20. (Continued)

STATION/Taxa	Date	Mean Density (Units/m^2) 1974	1975	1976	1978	1979	1980
STATION 29	APRIL						
Nematoda		..	117	20	13	7	..
Oligochaeta		..	1,602	853	648	292	26
Ephemeroptera		..	742	605	480	624	971
Plecoptera		..	91	157	77	52	123
Trichoptera		..	196	14	77	..	680
Diptera		..	85	13	78	..	52
Chironomidae		..	1,331	46	38	20	32
	JULY						
Oligochaeta		..	1,110	1,107	149	20	155
Ephemeroptera		..	20	4,194	1,031	936	1,146
Plecoptera		..	..	157	32	20	39
Trichoptera		..	..	358	142	33	123
Diptera		..	14	176	1,325	97	58
Chironomidae		..	33	191	115	65	52
	AUGUST						
Nematoda		..	39	..	..	..	..
Oligochaeta		..	671	1,346	26	39	..
Ephemeroptera		..	568	4,514	1,565	2,066	2,596
Plecoptera		..	7	864	55	..	201
Trichoptera		..	1,262	4,265	1,702	208	136
Diptera		..	306	163	78	26	104
Chironomidae		..	465	1,621	141	318	285

Table 4-20. (Continued)

STATION/Taxa	Date	Mean Density (Units/m^2) 1974	1975	1976	1978	1979	1980
STATION 29 - Continued							
	OCTOBER						
Nematoda		119	7	..	6	..	..
Oligochaeta		427	371	..	13	299	201
Ephemeroptera		1,165	1,802	..	928	3,515	272
Plecoptera		226	85	..	52	117	369
Trichoptera		1,974	527	..	273	936	3,372
Diptera		200	27	..	26	46	155
Chironomidae		303	282	..	..	812	1,288

1/ May was not sampled prior to 1979.

Table 4-21. Comparison of Diversity Indices of Macroinvertebrates During RBOSC MDP Studies (1978 and 1979) and RBOSC Aquatic Baseline Studies (1974-1976).

Location	Month	Index	Baseline 1974	Baseline 1975	Baseline 1976	MDP 1978	MDP 1979	MDP 1980
Station 13	April	Shannon	..	2.72	2.36	2.47	2.06	1.51
		Evenness	..	0.61	0.58	0.92	0.94	0.78
		No. of Species	..	22	17	7	9	7
	May[1/]	Shannon	..	..	..	..	1.08	1.67
		Evenness	..	..	..	..	0.78	0.93
		No. of Species	..	..	..	..	4	6
	June	Shannon	..	1.97	1.60	1.11	0.44	1.35
		Evenness	..	0.93	0.57	0.67	0.31	0.84
		No. of Species	..	5	5	3	4	5
	July	Shannon	..	2.51	3.65	0.86	1.02	0.85
		Evenness	..	0.90	0.78	0.67	0.57	0.37
		No. of Species	..	7	25	2	6	10
	August	Shannon	..	3.37	3.10	1.86	0.56	1.99
		Evenness	..	0.76	0.66	0.90	0.29	0.78
		No. of Species	..	21	26	2	6	13
	October	Shannon	2.79	2.34	..	0.96	1.47	1.85
		Evenness	0.60	0.59	..	0.35	0.64	0.80
		No. of Species	24	16	..	8	10	10
Station 14	April	Shannon	..	2.04	1.81	2.96	1.34	2.21
		Evenness	..	0.52	0.45	0.68	0.44	0.80
		No. of Species	..	15	17	21	10	16
	May[1/]	Shannon	..	..	..	..	0.42	1.74
		Evenness	..	..	..	..	0.17	0.68
		No. of Species	..	..	..	..	12	13

Table 4-21. (Continued)

Location	Month	Index	Baseline 1974	Baseline 1975	Baseline 1976	MDP 1978	MDP 1979	MDP 1980
Station 14 - Continued								
	June	Shannon	..	2.62	2.42	3.14	1.44	1.56
		Evenness	..	0.73	0.59	0.70	0.47	0.65
		No. of Species	..	12	18	23	22	11
	July	Shannon	..	1.54	3.44	2.77	1.74	1.25
		Evenness	..	0.41	0.75	0.61	0.61	0.57
		No. of Species	..	14	24	23	17	9
	August	Shannon	..	2.18	2.39	1.61	1.14	1.42
		Evenness	..	0.52	0.73	0.48	0.39	0.62
		No. of Species	..	18	6	10	18	10
	October	Shannon	2.33	3.14	..	1.97	1.49	1.65
		Evenness	0.61	0.79	..	0.48	0.57	0.72
		No. of Species	15	16	..	12	14	10
Station 20	April	Shannon	..	2.74	2.17	2.65	1.66	1.57
		Evenness	..	0.69	0.65	0.69	0.86	0.81
		No. of Species	..	16	10	15	8	7
	May[1/]	Shannon	..	..	..	..	1.66	2.20
		Evenness	..	..	..	..	0.65	0.89
		No. of Species	..	..	..	..	13	12
	June	Shannon	..	2.81	2.45	2.67	1.59	1.20
		Evenness	..	0.79	0.65	0.73	0.69	0.61
		No. of Species	..	12	14	13	10	7
	July	Shannon	..	1.74	2.74	3.16	0.82	0.93
		Evenness	..	0.53	0.67	0.81	0.29	0.52
		No. of Species	..	10	17	15	16	6

Table 4-21. (Continued)

Location	Month	Index	Baseline 1974	Baseline 1975	Baseline 1976	MDP 1978	MDP 1979	MDP 1980
Station 20 - Continued								
	August	Shannon	..	2.51	2.19	2.47	1.78	1.49
		Evenness	..	0.85	0.59	0.59	0.66	0.72
		No. of Species	..	8	13	18	15	8
	October	Shannon	..	2.76	2.47	1.41	1.84	0.81
		Evenness	..	0.74	0.65	0.48	0.68	0.45
		No. of Species	..	14	14	8	15	6
Station 21	April	Shannon	..	2.42	2.38	2.75	1.64	1.25
		Evenness	..	0.65	0.81	0.71	0.66	0.77
		No. of Species	..	13	8	15	12	5
	May [1/]	Shannon	..	..	..	..	1.28	1.70
		Evenness	..	..	..	..	0.59	0.82
		No. of Species					9	8
	June	Shannon	..	2.97	2.74	2.79	1.37	1.37
		Evenness	..	0.70	0.64	0.77	0.70	0.62
		No. of Species	..	18	18	13	7	9
	July	Shannon	..	2.65	3.21	3.47	1.26	1.60
		Evenness	..	0.75	0.77	0.74	0.47	0.67
		No. of Species	..	12	18	26	15	11
	August	Shannon	..	3.03	1.45	2.27	1.91	1.91
		Evenness	..	0.87	0.47	0.55	0.64	0.69
		No. of Species	..	11	9	18	20	16
	October	Shannon	2.43	2.42	..	1.52	1.82	2.18
		Evenness	0.71	0.62	..	0.48	0.63	0.81
		No. of Species	11	15	..	9	18	15

Table 4-21. (Continued)

Location	Month	Index	Baseline 1974	Baseline 1975	Baseline 1976	MDP 1978	MDP 1979	MDP 1980
Station 27	April	Shannon	..	3.04	2.40	3.35	1.50	1.62
		Evenness	..	0.79	0.57	0.69	0.65	0.83
		No. of Species	..	17	19	20	10	7
	July	Shannon	..	1.72	2.73	3.15	2.31	2.24
		Evenness	..	0.97	0.66	0.86	0.72	0.85
		No. of Species	..	4	18	9	25	14
	August	Shannon	..	3.28	3.72	2.93	1.87	1.96
		Evenness	..	0.78	0.81	0.72	0.57	0.74
		No. of Species	..	19	24	17	26	14
	October	Shannon	3.61	4.04	..	2.48	2.23	1.59
		Evenness	0.83	0.83	..	0.73	0.70	0.56
		No. of Species	20	29	..	10	24	17
Station 29	April	Shannon	..	3.49	2.94	3.41	1.64	1.43
		Evenness	..	0.71	0.79	0.89	0.66	0.58
		No. of Species	..	30	14	15	12	12
	July	Shannon	..	1.37	3.47	2.58	1.45	1.72
		Evenness	..	0.53	0.73	0.66	0.54	0.67
		No. of Species	..	7	27	16	15	13
	August	Shannon	..	3.73	3.67	2.94	1.61	2.12
		Evenness	..	0.79	0.81	0.70	0.55	0.72
		No. of Species	..	26	23	19	19	19
	October	Shannon	..	3.41	3.58	2.23	2.25	1.46
		Evenness	..	0.72	0.73	0.71	0.69	0.54
		No. of Species	..	27	30	9	26	15

1/ May was not sampled prior to 1979.

In 1980, there was increased discharge from the RBOSC mine site, consistently raising the water level and causing swifter flows than previously recorded. The general increase in numbers of organisms may be explained by an increase in habitat availability. Chironomidae and Simuliidae are also generally indicative of disturbed streams. Since both of these groups have short life cycles, they are able to colonize disturbed areas and become dominant. Simuliidae tend to aggregate in areas of swift flow since they rely on the flow of water to carry food to them. Both Simuliidae and some Ephemeroptera (Baetis sp.) can tolerate a wide range of water hardness and can survive in areas where the discharge has high dissolved solids. In October, when the black flies had emerged and flow was less, there was a greater number of Oligochaeta (Tubificidae, Naididae) and Muscidae which tolerate a silty substrate. A plecopteran, Chloroperlidae, was found at Station 13 in August and October. This stonefly is long and thin and specially adapted to burrow into the silty substrate of streams.

Species diversity for Station 13 ranges from 0.85 to 1.99, indicating a disturbed area. In comparing 1980 diversity values to the 1979 values, diversity decreased in April and July and increased in June, August and October 1980. This is difficult to explain except that a disturbed and fluctuating habitat is present.

In summary, data from the 1980 macroinvertebrate sampling indicates that Station 13 is continuing to be affected by project activities. This observation is reflected by the large numbers of Chironomidae and Simuliidae, as well as an abundance of organisms which tolerate or prefer silt-laden substrates. Other groups of Insecta were virtually nonexistent.

There has been considerable habitat alteration at Station 14 over the years: in late winter of 1980, the earthen dam broke causing the "pond" to drain. The resulting "stream" habitat became a "pond" once again as soon as the dam was repaired. Most of the organisms found at this site in 1980 are indicative of a disturbed area. Chironomidae was by far the most abundant taxa during every sampling period. Simuliidae was not a major group at Station 14, though it was present. The flow was generally much slower at Station 14 than at Station 13. Simuliidae need fast flow. Oligochaeta were abundant in May (Naididae) and in August and October (Tubificidae). Tipulidae (Diptera) was a prominent group in

July, August and October. The fauna from June to October was indicative of an area in the recovery stage; the main groups were Oligochaeta, Chironomidae (Baetis sp.), and Tipulidae.

The greatest density of macroinvertebrates at Station 14 occurred in April and July and was composed mainly of Chironomidae. Diversity values at Station 14 range from 1.25 to 2.21. These numbers are not drastically different from the 1979 values at the same time.

Fewer taxa were found at Station 14 in 1980 than in 1979, perhaps due to disturbance from upstream activities that occurred during 1980. Species found in 1979 but not in 1980 were Ephemerella inermis, Callibaetis sp., Cheumatopsyche sp., and Hydropsyche sp.. In July and August 1979, tremendous numbers of Oligochaeta and Chironomidae were counted. In the same months of 1980, total density was lower. In 1979, much silt had been deposited forming an ideal habitat for Oligochaeta and Chironomidae. In 1980, some of this depositional material had washed downstream when the dam broke, reducing habitat and resulting in smaller numbers of these groups.

In 1980, the species composition and densities of organisms at Station 20 on Yellow Creek were very similar to 1979 data. Chironomidae (Diamesa sp. and Orthocladius sp.) was the dominant group except in June, July and August when Simuliidae was very abundant. The large numbers of these organisms indicate an unstable environment characterized by large fluctuations in flow and silt deposition (Merritt and Cummins 1978) which is a natural condition for Yellow Creek (Table 4-20). Tricorythodes sp. (Ephemeroptera), a "silt lover", a few Coleopterans (Dytiscidae), and Hydropsyche sp. (Trichoptera) were found throughout the 1980 sampling period, as in 1979, yet their numbers were again very low.

Fewer taxa were identified in 1980 at Station 20 than in 1979. Diversity values were also slightly lower than in 1979. They ranged from 0.81 to 1.57. The macroinvertebrate fauna at Station 21 in 1980 was very similar to Station 20 in density and species composition except during the October sampling period. At that time, Baetis sp., Dactylobaetis sp., Ophiogomphus (Odonata) and Hyalella azteca (Amphipoda) were found at this station. Diversity values in 1980 for

Station 21 were very similar to those in 1979. The range of values in 1980 were from 1.25 to 2.18 and were generally higher than values at Station 20.

In summary, Stations 20 and 21 do not represent a highly diverse area. The macroinvertebrate communities at these stations have remained consistent throughout the baseline and monitoring programs. Diversity values and species composition for these stations characterize a small stream in the semi-arid west which has a relatively silty substrate, high dissolved solids, and great fluctuations in flow. There was little change, if any, in the total mean densities for 1979 and 1980; however, a general drop in species diversity over previous study years (1975-1978) was noted.

Ephemeroptera remained the dominant macroinvertebrate group in 1980 at Station 27 on the White River. The main mayfly groups counted were Baetis sp., Ephemerella inermis, Rhithrogena sp., Tricorythodes sp., Choroterpes sp., and Traverella albertana. The Trichopteran, Hydropsyche sp., was also very abundant throughout the sampling period as in other years. Chironomidae (Orthocladius, Procladius, Eukiefferiella) was present in large numbers in October and less dominant but present during other months. Plecoptera was present in fewer numbers for all dates compared to 1979 as was Oligochaeta.

Density values for macroinvertebrates were similar to 1979 data and follow the general seasonal pattern for macroinvertebrate communities in streams of low spring and high fall numbers. Diversity values range from 1.59 to 2.24 for 1980, values which are very similar to those calculated from 1979 data.

Station 29, below the confluence with Yellow Creek, was very similar to Station 27 in macroinvertebrate densities, diversity, and species composition. Ephemeroptera was the dominant group, with Trichoptera also abundant. Other taxa found were Oligochaeta, Plecoptera, Odonata and some Diptera (Chironomidae, Simuliidae, Tipulidae). Diversity values for Station 29 ranged from 1.43 to 2.12, also similar to 1979 values. Density values for Station 29 were slightly higher than the values for Station 27. This could be due to natural enrichment of the White River contributed by Yellow Creek which would tend to increase numbers slightly.

In summary, the macroinvertebrate community of Station 27 above Yellow Creek is virtually the same as the community of Station 29 below Yellow Creek. Species composition and diversity represent a well-balanced stable river community with no adverse effect from the outflow of Yellow Creek. There has been no apparent change from the data of 1979 and none from the data of other years for both of these stations. In 1980, Stations 27 and 29 had a diverse community indicative of a river of a semi-arid region; a river with a large percentage of silt with rubble substrate and high dissolved solids.

4.3 DATA ANALYSIS

A. Statistical Analysis of RBOSC Periphyton Density

1. Summary of the Statistical Analysis

Total periphyton density was analyzed using a three-way analysis of variance. Mean differences in density between 1979 and 1980, among sampling seasons within each year, and among sampling stations were tested for statistical significance. The interactions between sampling stations and the sampling year were included in the analysis. Mean differences in periphyton density among sampling seasons within each year's station combination were also compared.

2. Results of the Analysis

The results of the analysis are summarized in Appendix 4-3. The two years' total mean densities were not significantly different. However, densities for 1979 and 1980 seasons were significantly different. During these years, fall values were significantly different than the values for spring and summer. The 1979 and 1980 periphyton densities at Stations 13, 14 and 29 were not significantly different. During this two year period, Stations 13, 20, 21, 27 and 29 periphyton densities also did not differ significantly. However, significant differences in periphyton densities did occur between Station 14 and Stations 20, 21 and 27.

B. Statistical Analysis of RBOSC Benthos Density

1. Summary of the Statistical Analysis

The densities of selected benthos groups were analyzed using a three-way analysis of variance. Groups chosen were Chironomidae, Coleoptera, Ephemeroptera, Nematoda, Odonata, Oligochaeta, Plecoptera and Trichoptera. Mean differences in density between years, seasons and sampling stations were tested for statistical significance for 1979 and 1980. Mean differences in density among sampling stations within year-sampling stations combinations were also compared.

2. Results of the Analysis

Results of the analysis are summarized in Appendix 4-3.1. There were no significant differences between 1979 and 1980 in the mean groups densities of the Chironomidae, Coleoptera, Plecoptera and Trichoptera. However, there were significant differences between years for the Ephemeroptera, Nematoda, Odonata and Oligochaeta. There was a significant difference in the mean densities of Ephemeroptera, Odonata, Plecoptera and Trichoptera among sampling seasons within each year. Chironomidae, Coleoptera, Nematoda and Oligochaeta showed no significant differences in mean density among sampling seasons within each year.

There was a significant difference in the mean densities among stations for all the groups. The stations by year interaction was non-significant in the mean density of Chironomidae, Coleoptera and Trichoptera. However, significant differences in this interaction occurred for the Ephemeroptera, Nematoda, Odonata, Oligochaeta and Plecoptera. Also, the season by station interaction displayed a significant difference in groups mean densities of Chironomidae, Ephemeroptera, Odonata, Plecoptera and Trichoptera. No significant differences were apparent in the season by station interaction for the Coleoptera and Nematoda. The year season station interaction showed a significant difference in group mean densities for the Ephemeroptera, Odonata and Plecoptera. Other groups in this interaction were not significantly different.

Station 14 mean densities of the Chironomidae, Nematoda and Oligochaeta were significantly different than the groups' mean densities at the other stations. The mean densities for the Chironomidae, Nematoda and Oligochaeta for Stations 13, 20, 21, 27 and 29 were statistically similar. However, Station 21 Coleoptera mean densities were significantly different than Stations 13, 14, 27 and 29.

The Ephemeroptera mean densities at Stations 27 and 29 were not significantly different and the mean density of this group was not significantly different at Stations 13, 14, 20 and 21. However, Stations 27 and 29 Ephemeroptera mean densities were significantly different from Stations 13, 14, 20 and 21.

The Odonata mean densities were not significantly different at Stations 21 and 27. Station 21 Odonata mean densities were significantly different than this groups' densities at Stations 13, 14, 20 and 29. However, Station 27 mean densities for this order was not significantly different than Stations 13, 14, 20 and 29.

Station 29 Plecoptera mean densities were significantly different than the other stations (as were the values for Station 13). Stations 14. 20 and 21 mean densities for Plecoptera were not significantly different. The mean densities for Trichoptera at Stations 27 and 29 were significantly different and each was significantly different than the other stations. The Trichoptera mean densities of Stations 13, 14, 20 and 21 were not significantly different.

Mean densities of the silt-tolerant groups, Oligochaeta, Chironomidae, and Nematoda, were not statistically different at Stations 13, 20, 21, 27 and 29. The only station in which these groups were significantly different was Station 14, reflecting the difference in habitat type at Station 14. Station 14 was a pond habitat while the other stations were streams.

The mean densities of the macroinvertebrate groups analyzed, other than the Odonata, were not significantly different at Stations 20 and 21 which indicates the similarity of habitats at these two stations. Stations 27 and 29 mean benthos densities for the major taxonomic groups were not significantly different with the exception of the Plecoptera and the Trichoptera. Therefore, the statistical analysis of the major zoobenthic groups at Stations 27 and 29 suggests that Tract C-a activities had no adverse effects on the density of the White River benthic fauna during April - October 1979 and 1980.

4.4 SUMMARY

Physical parameters examined at each of the aquatic sampling stations indicate seasonal as well as annual variability. Few trends or major changes in the physical measurements can be detected from the data. Stations 13 and 14 experienced an increase in the volume of flow which was probably due to operational water discharge into Corral Gulch. As a result, the depth and width of the stream channel and velocity of flow increased at Station 13. Higher turbidity recorded at this location was probably a result of the additional discharge.

Water quality measurements made in 1980 indicate no large changes in White River water quality upstream or downstream from its confluence with Yellow Creek. Examination of the 1980 data, as well as the data collected in the baseline and early monitoring studies, also shows no major differences in the water quality at aquatic sampling stations on or near Tract C-a. All analyses were performed according to EPA standards.

A total of 201 periphyton taxa consisting of 157 diatoms (Bacillariophyta), 26 green algae (Chlorophyta), 1 yellow-green alga (Chrysophyta), 12 blue-green algae (Cyanophyta), 2 euglenoids (Euglenophyta), and 3 red algae (Rhodophyta) was identified from the periphyton collected during 1980.

Mean density values ranged from a high of 10,196 units/mm^2 at Station 29 to a low of 194 units/mm^2 at Station 13. Annual variations in periphyton densities occur on a seasonal basis and are directly related to such highly variable environmental parameters as current velocity, temperature, light, spring runoff, turbidity and substrate type. The 1980 density and biomass estimates at Station 13 were generally lower than the 1979 values, but the 1980 estimates for all other stations were higher than in 1979. The 1980 estimates for Station 13 were the lowest recorded since the beginning of RBOSC aquatic studies, probably due to the surface discharge and subsquent substrate scouring which resulted.

During baseline studies, Achnanthes spp. (primarily Achnanthes minutissima) dominated the periphyton at Station 13. Taxa dominant at this station during

the 1980 MDP studies but not during the baseline studies were the blue-green alga, Phormidium sp., in the spring, the green algae, Cladophora sp., Microspora sp., Spirogyra sp. and Zygnema sp. in the summer, as well as the red alga, Batrachospermum sp., in the fall. This change in dominant species may have been due to the increase in turbidity and flow of water at Station 13. Differences in species dominance are not uncommon in aquatic communities that have a high degree of variability in environmental parameters such as stream velocity and turbidity.

Stations 20 and 21 on Yellow Creek have spring and fall periphyton communities which appear to be dominated by a group of diatoms whose relative abundance varies annually. The summer trend of green algal dominance at Stations 20 and 21 has increased during the MDP monitoring studies from 1978 through 1980. Station 27 on the White River, upstream from any project influence, has shown changes in periphyton density, biomass and species diversity similar to Station 29 which is on the White River downstream from the confluence of Yellow Creek. Therefore, it appears that Tract C-a project activities are having little or no effect on the periphyton communities of the White River.

Corral Gulch is directly affected by project related activity on Tract C-a. Station 13 is located in an unstable area characterized by fluctuations in flow, silt load and dissolved solids. The macroinvertebrate fauna is indicative of disturbance and is tolerant of such conditions. Station 14 is located in an unstable area where water level and velocity have changed several times due to the breaking of the dam and activities related to its repair. The fauna here, too, is indicative of disturbance.

Yellow Creek is a small creek affected by natural fluctuations in flow and silt load. Stations 20 and 21 have similar macroinvertebrate communities characterized by organisms tolerant of unstable conditions. It appears that Tract C-a activities do not affect the biota of lower Yellow Creek.

The White River does not appear to have been directly affected by mining activities on Tract C-a. The macroinvertebrate communities at Stations 27 and 29 can be described as diverse, stable and normal for a river of the size and location of the White River.

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SECTION 5
HYDROLOGY STUDIES

This report presents the data and analysis from the Rio Blanco Hydrology Monitoring Program (Tract C-a) for the 1980 Report Year (December 1979 through November 1980). The purpose of this presentation is to provide a comparison of the 1980 Report Year data with observations from the baseline period. In addition, all data available at this time for the report year are provided.

The discussion of the monitoring program has been divided into three sections: surface water, groundwater, and development activities monitoring. The surface water monitoring program includes data from U.S. Geological Survey (USGS) gaging stations located on or near Tract C-a and data from springs and seeps in the area. Groundwater data have been collected from alluvial, upper aquifer, and lower aquifer monitor wells.

The development activities monitoring program includes sampling of the quantity and quality of waters displaced as a result of development operations on Tract C-a. Monitoring stations include ponds, piezometers, leachate collectors, flumes (and other surface flow monitoring sites), and the various components of the dewatering/reinjection system. This monitoring takes place in the immediate proximity of development activities.

Brief data summaries and analysis results needed to support discussion of the monitoring data are presented in the following pages. Raw data listings are provided in Volume 4--Appendices. Sampling locations are shown on Map 1 (see map pocket).

The hydrology monitoring program and the associated data management and data analysis activities are being upgraded at this time to enhance the utility of the data collected. Ongoing activities include compiling and reformatting the data bases and screening to identify spurious data (e.g., from data entry errors). Consistent formats for plotting and tabulating the data are being designed to provide for efficient evaluation of data as they are collected. In addition, statistical analyses are being performed for evaluation of existing data and redesign of future data analysis approaches.

Because these activities are currently in progress, the data analyses and presentations provided in this report constitute part of a transition to the proposed modified monitoring program. The results of the data base/data management redevelopment will be provided either in the form of the 1981 mid-year report or as a separate submittal. Thus, this report provides an interim analysis of the 1980 report year data.

5.1 SURFACE WATER

A. Streams

1. Objectives

The objective of the stream monitoring program is to evaluate changes in stream flow and water quality as measured at USGS stream gages. For this report, the 1980 water year (October 1979 through September 1980) is compared to the baseline water years 1975 and 1976.

2. Methods

The USGS monitors surface water quantity (flow) and quality at six gaging stations in the vicinity of Tract C-a (Table 5-1). Conductivity, pH, temperature, and flow are monitored continuously at these gaging stations. Water chemistry samples (grab samples) are collected on a quarterly and semiannual basis (Table 5-2).

Table 5-1. U.S. Geological Survey Surface Gaging Stations, 1980 Water Year, Tract C-a

USGS I.D. No.	Tract Station	Description
09306237	A	Dry Fork near West Tract Boundary
09306235	B	Corral Gulch near West Tract Boundary
09306240	C	Box Elder Gulch near West Tract Boundary
09306242	D	Corral Gulch near East Tract Boundary
09306241	E	Box Elder Tributary near East Tract Boundary: "Rinky Dink Gulch"
09306255	F	Yellow Creek near White River

Table 5-2. Water Chemistry Sampling Program at USGS Surface Water Gaging Stations, 1980 Water Year, Tract C-a

Quarterly Sampling	Semiannual Sampling	
pH	Bromide	Radioactivity:
Alkalinity	Biological Oxygen Demand	
Calcium	Dissolved Organic Carbon	Gross Alpha
Magnesium	Boron	Ra-226[1/]
Sodium	Selenium	Natural Uranium
Potassium	Conductance	Gross Beta
Chloride		Sr-90[2/]
Sulfate	Chemical Oxygen Demand	Ce-137[2/]
Bicarbonate	Fecal Coliform	
Carbonate	Pesticides	Silver
Fluoride	Nitrogen, Ammonia	Ortho Phosphate
Silica (SiO_2)	Total Coliform	Tin
	Strontium	Aluminum
	Cyanide	Arsenic
		Cadmium
	MBAS	Chromium
	Oil and Grease	Selenium
	Ammonia	Mercury
	Color	Zinc
	Hardness	Iron
	Dissolved Solids	Lead
	Suspended Solids	
	Kjeldahl Nitrogen	Spectrographic Analysis:
	Nitrate Plus Nitrite	
	Odor	Molybdenum
	Dissolved Phosphate	Lithium
	Turbidity	Manganese
	Dissolved Oxygen	Barium
	Phenols	Beryllium
	Sulfide	Germanium
	Temperature	Gallium
		Nickel
		Titanium
		Vanadium
		Zirconium
		Copper

1/ Ra^{226} analysis will be conducted only if gross alpha activity is greater than 4 pci/l

2/ Sr^{90} and Ce^{137} analysis well be conducted only if gross beta activity is greater than 100 pci/l

USGS water quality data for the 1980 water year are presented in Appendix 5-1.1. Computer-compatible data from the continuous monitors for the 1980 water year were not available at the time of development of this report. These data will be provided in the 1981 mid-year report.

3. Results and Discussion

a. Continuous Monitors - Physical data (flow-specific conductance, pH, and temperature) for the reporting period from continuous monitors were not available from USGS for this report. Background data summaries which will be used to evaluate the 1980 water year results are presented in Appendix 5-1.2.

b. Water Quality - Water quality data collected by the USGS are tabulated in Appendix 5-1.1. No data were reported by the USGS for the 1980 water year for Station A.

For this report, the water quality data were evaluated in two ways. Means and ranges for the 1980 water year were compared to means and maximum values for water years 1975 and 1976 (baseline period). In addition, multivariate ANOVA (MANOVA) was performed using selected chemical constituents to evaluate differences between water years. The data evaluations have been confined to major inorganic ions (bicarbonate, chloride, sulfate, fluoride, silica, calcium, magnesium, sodium, and potassium); selected trace constituents (arsenic, molybdenum, vanadium, selenium, and mercury); and general water quality measures (specific conductance, pH, alkalinity, dissolved organic carbon (DOC), and total dissolved solids (TDS)).

The results of the comparison of means and maximum values are shown in Tables 5-3 through 5-7 (for stations B, C, D, E, and F, respectively (no samples were collected at Station A during water year 1980)). In general, differences observed at Stations B, D, E, and F were not appreciable, particularly for mean values. The differences noted in specific conductance, maximum concentrations of several major inorganic ions, and DOC at Stations D may be related to occasional mine water discharges in the Corral Gulch watershed.

Table 5-3. General Comparison of Water Quality at Gaging Station B, Water Years 1975, 1976, and 1980 (data listed show 1980 means or maximum values which exceed 1975 or 1976 data)

	Station B			
	1980 Mean[3]		1980 Maximum[3]	
Constituent[1]	≥1975	≥1976	≥1975	≥1976
Specific Conductance	..	..	..	1170/1100
pH	..	..	..	8.4/8.3
Alkalinity	..	..	..	360/343
HCO_3	..	..	..	..
Ca	..	..	100/93	100/96
Mg	..	..	68/67	68/57
Na	..	..	..	..
K	1.6/1.3	1.6/1.6	3.5/1.6	3.5/2.8
Cl	..	..	9.8/9.5	..
SO_4	..	..	..	..
F	0.28/0.28	..	..	0.3/0.3
As	5.8/4.6	5.8/5.7	..	8/8
Mo[2]	..	..	..	..
V[2]	..	..	..	..
Se	4.2/4.1	4.2/3.6	..	5/5
Hg[2]	..	..	..	0.1/0.1
DOC	..	10.8/8.9	17/12	17/16
TDS	..	..	..	..
SiO_2	..	..	23/23	23/22

[1] Units: specific conductance - µmhos/cm at 25°C; pH - pH units; As, Mo, V, Se, and Hg - µg/l; others - mg/l

[2] One 1980 sample, compared to baseline maximum values

[3] Where 1980 mean or maximum value equals or exceeds 1975 or 1976 value the data are listed as 1980 value/1975 value or 1980 value/1976 value. Unless otherwise indicated, the .. indicates that the 1980 value was less than the baseline year value.

Table 5-4. General Comparison of Water Quality at Gaging Station C, Water Years 1975, 1976, and 1980 (data listed show 1980 means or maximum values which exceed 1975 or 1976 data)

	Station C			
	1980 Mean[5]		1980 Maximum[5]	
Constituent[1]	≥1975	≥1976	≥1975	≥1976
Specific Conductance	..	600/588	..	..
pH	..	..	..	8.1/8.1
Alkalinity	..	203/185	290/290	290/254
HCO_3[2]	..	..	..	..
Ca	..	51/40	79/75	79/54
Mg	..	33/32	48/47	48/48
Na	..	40/38	57/56	..
K	5.9/1.0	5.9/4.3	16/1.5	16/11
Cl	9.2/5.6	9.2/4.8	18/6	18/6
SO_4	..	132/109	220/170	220/180
F	0.3/0.3	0.3/0.2	0.4/0.4	0.4/0.3
As[3]	..	..	..	..
Mo[2]	..	..	..	..
V[2]	..	..	..	..
Se[3]	..	..	5/5	5/3
Hg[2]	..	..	..	..
DOC	..	17.7/15	30/9[4]	..
TDS	..	412/358	626/527	626/505
SiO_2	..	..	23/23	..

[1] Units: specific conductance - µmhos/cm at 25°C; pH - pH units; As, Mo, V, Se, and Hg - µg/l; others - mg/l

[2] Not sampled in water year 1980

[3] Only one sample in water year 1980

[4] Single sample in 1975

[5] Where 1980 mean or maximum value equals or exceeds 1975 or 1976 value the data are listed as 1980 value/1975 value or 1980 value/1976 value. Unless otherwise indicated, the .. indicates that the 1980 value was less than the baseline year value.

Table 5-5. General Comparison of Water Quality at Gaging Station D, Water Years 1975, 1976, and 1980 (data listed show 1980 means or maximum values which exceed 1975 or 1976 data)

	Station D			
	1980 Mean[3]		1980 Maximum[3]	
Constituent[1]	≥1975	≥1976	≥1975	≥1976
Specific Conductance	1370/1254	1370/1223	..	1550/1320
pH	7.9/7.9	7.9/7.8	8.4/8.3	8.4/8.2
Alkalinity	..	401/386	..	490/419
HCO_3	..	486/470	..	530/511
Ca	..	..	..	96/91
Mg	64/63	64/61	80/71	80/70
Na	137/129	137/110	..	180/130
K	1.9/1.6	1.9/1.6	4.4/2.4	4.4/2.4
Cl	..	..	..	14/12
SO_4	304/285	304/278	400/360	400/310
F	..	0.6/0.4	..	1.3/0.6
As	5.2/4.8	5.2/4.8	..	..
Mo[2]	..	..	56/56	56/50
V[2]	..	..	4/4	4/4
Se	..	2.6/2.5	..	..
Hg[2]	..	..	..	0.1/0.1
DOC	18/10.7	18/7.3	25/14	25/14
TDS	854/853	854/800	..	1080/871
SiO_2	22/20	22/21	26/23	26/22

[1] Units: specific conductance - µmhos/cm at 25°C; pH - pH units; As, Mo, V, Se, and Hg - µg/l; others - mg/l

[2] Only one sample during water year 1980

[3] Where 1980 mean or maximum value equals or exceeds 1975 or 1976 value the data are listed as 1980 value/1975 value or 1980 value/1976 value. Unless otherwise indicated, the .. indicates that the 1980 value was less than the baseline year value.

Table 5-6. General Comparison of Water Quality at Gaging Station E, Water Years 1975, 1976, and 1980 (data listed show 1980 means or maximum values which exceed 1975 or 1976 data)

	Station E			
	1980 Mean[1/4/]		1980 Maximum[1/4/]	
Constituent[2/]	≥1975	≥1976	≥1975	≥1976
Specific Conductance	..	..	..	..
pH	..	..	..	..
Alkalinity	..	..	..	..
HCO_3[3/]	..	..	..	..
Ca	..	..	..	20/17
Mg	..	..	..	..
Na	..	..	..	..
K	..	..	..	5.5/2.9
Cl	..	..	..	2/1.8
SO_4	..	..	..	..
F	..	..	..	..
As	..	..	..	..
Mo[3/]	..	..	..	..
V[3/]	..	..	..	..
Se[3/]	..	..	..	..
Hg	..	..	..	0.1/0.1
DOC	..	..	..	..
TDS	..	..	..	..
SiO_2	..	..	..	..

1/ Only one sample collected in 1980, none in 1975; thus, only 1980 data and 1976 maximum values were compared

2/ Units: specific conductance - µmhos/cm at 25°C; pH - pH units; As, Mo, V, Se, and Hg - µg/l; others - mg/l

3/ No data for water year 1980

4/ Where 1980 mean or maximum value equals or exceeds 1975 or 1976 value the data are listed as 1980 value/1975 value or 1980 value/1976 value. Unless otherwise indicated, the .. indicates that the 1980 value was less than the baseline year value.

Table 5-7. General Comparison of Water Quality at Gaging Station F, Water Years 1975, 1976, and 1980 (data listed show 1980 means or maximum values which exceed 1975 or 1976 data)

	Station F			
	1980 Mean[4]		1980 Maximum[4]	
Constituent[1]	≥1975	≥1976	≥1975	≥1976
Specific Conductance	..	..	..	..
pH	..	..	..	..
Alkalinity	..	..	..	..
HCO_3	1496/1473	1496/1471	1990/1930	1990/1990
Ca	..	..	..	..
Mg	..	..	..	..
Na	..	..	880/870	..
K	4.8/4.3	4.8/4.8	..	..
Cl	..	..	160/150	..
SO_4	..	..	..	..
F	..	..	2.8/2.5	..
As	5.4/5.8	..	..	..
Mo[2]	..	..	..	..
V[2]	..	..	..	..
Se	2.2/2.2	2.2/2.0	3/3	3/3
Hg[3]	..	..	..	..
DOC	32.6/13.7	32.6/11.6	43/22	43/43
TDS	..	..	..	..
SiO_2	..	..	..	..

[1] Units: specific conductance - µmhos/cm at 25°C; pH - pH units; As, Mo, V, Se, and Hg - µg/l; others - mg/l

[2] One 1980 sample

[3] No 1980 samples

[4] Where 1980 mean or maximum value equals or exceeds 1975 or 1976 value the data are listed as 1980 value/1975 value or 1980 value/1976 value. Unless otherwise indicated, the .. indicates that the 1980 value was less than the baseline year value.

Similarly, specific conductance and several major inorganic ion concentrations at Stations D were identified in the 1979 year-end report as being elevated relative to baseline conditions. These changes were concluded to reflect dewatering discharges.

Station C is upstream from tract activities and, thus, the differences noted in concentrations of several major ions between baseline and 1980 data (e.g., calcium, potassium, chloride, sulfate, and TDS) are a reflection of natural variability. Station F is located several miles downstream from the tract and is separated from tract influences by dry alluvium. Thus the differences from the baseline noted here are also a reflection of natural variability.

The MANOVA examination of differences across report years is summarized in Table 5-8. Significant differences among the report years were noted for temperature, pH, calcium, magnesium, sulfate, molybdenum, vanadium, and DOC. a Duncan's multiple range test was used where the main effects test was significant. The 1980 water year data were different from baseline (1975 and 1976) water years for only molybdenum and DOC. For the most part, the change in average DOC values was due to changes in DOC between the baseline and 1980 at Stations D and F.

The overall conclusion of this evaluation is that stream water quality as observed at the USGS gages was not significantly different from the baseline perion although certain constituents have changed to some extent.

B. Springs and Seeps

1. Objectives

The major objective of the springs and seeps program is to monitor physical parameters (flow, conductivity, temperature, and pH) and to evaluate any changes relative to baseline observations. Water chemistry data were also collected at selected springs and seeps during the 1980 report year. Baseline data collected near the existing sampling sites are presently being evaluated for use in the current data collection/evaluation program.

Table 5-8. Summary of MANOVA of Differences in Water Quality Over Water Years on Record, USGS Stream Gaging Data (Duncan's test results show years significantly different from 1980 water year)

Variable	MANOVA Results		Duncan Test
	Pr > F[1/]	Significant[2/]	Water Years Significantly Different From 1980
Temperature	0.0148	*	1965
Flow	0.4033		
Specific Conductance	0.0702		
pH	0.0165	*	None
HCO_3	0.098		
CO_3	0.1054		
Ca	0.0018	*	1974
Mg	0.0487	*	1965, 1973, 1977, 1978
Na	0.1874		
K	0.5557		
Cl	0.0753		
SO_4	0.0286	*	1965
F	0.3127		
As	0.1010		
Mo	0.0101	*	1976, 1978, 1979
V	0.0321	*	1978
Se	0.2870		
Hg	0.9228		
DOC	0.001	*	1965, 1972-1979
TDS	0.1137		

1/ Pr > F: probability of greater F value; if Pr > F is small (e.g. <0.05), it indicates significance

2/ At 5% level

2. Methods

Seven springs and seeps were monitored during the 1980 report year (Table 5-9). Specific conductance and pH are measured quarterly using field instruments. Discharge is measured by using a weir, or flume, or by integrating cross-section and velocities data. Water quality samples are collected as grab samples.

Table 5-9. Springs and Seeps Sampling Stations, 1980 Report Year, Tract C-a

Station	Name	Drainage
SPG-01	Cathedral Bluffs	Box Elder Gulch southwest of Tract
SPG-02	Spruce Gulch	Box Elder Gulch southwest of Tract
SPG-03	Maverick Spring	Corral Gulch west of Tract
SPG-04	Water Gulch	West of Tract
SPG-05	Stake Springs Draw	Southwest of Tract
SPG-08	Box Elder Gulch	On-Tract
SPG-14	84-Ranch	Corral Gulch east of Tract

3. Results and Discussion

Field data collected at the springs and seeps stations from the baseline period through the 1980 report year are summarized in Table 5-10. The temperature, conductivity, and pH data for 1980 are generally comparable to data observed earlier in the monitoring program.

Springs and seeps data for the 1980 report year are presented in Appendix 5-1.3.

C. Erosion and Sedimentation

Scouring and sediment deposition were estimated by monitoring changes in stream channel cross-section profiles. Ten monitoring stations are included in this program (Table 5-11). The analysis of the erosion and sedimentation data is presently being modified to provide a more quantitative measure of these hydrologic processes. These analysis techniques and the results of 1980 report year data analysis will be included in the 1981 mid-year report.

Table 5-10. Summary of Field Data Collected at Springs and Seeps, Tract C-a

Station	Parameter[1/]	Statistic	Report Year: Baseline 1975-76	1977	1978	1979	1980
SPG-01	Flow	Maximum	..	21.0	48.0	20.0	150
		Minimum	..	..	5.0	1.0	..
	Temperature	Maximum	19	6.0	8.0	8.3	7.8
		Minimum	1	..	7.5	7.5	7.7
	Specific Conductance	Maximum	950	920	910	850	920
		Minimum	825	..	870	800	750
	pH	Maximum	..	..	7.4	7.5	7.6
		Minimum	..	..	7.1	7.1	7.1
SPG-02	Flow	Maximum	..	13.0	68	255	495
		Minimum	..	..	6	0.1	..
	Temperature	Maximum	11	..	9.0	9.0	9.0
		Minimum	7	..	8.0	8.5	8.0
	Specific Conductance	Maximum	1200	1000	990	1120	1010
		Minimum	1000	..	990	800	910
	pH	Maximum	..	..	7.2	7.7	7.6
		Minimum	..	..	7.2	7.0	7.5
SPG-03	Flow	Maximum	..	21	9	49	32
		Minimum	..	..	9	0.7	42
	Temperature	Maximum	2.0	1.0	7	13.8	11.0
		Minimum	5.0	..	5	7.5	2.0
	Specific Conductance	Maximum	1300	1025	1280	1300	1460
		Minimum	850	..	1250	950	1000
	pH	Maximum	..	..	7.6	9.2	8.2
		Minimum	..	..	7.1	7.0	8.0

Table 5-10. (Continued)

Station	Parameter[1/]	Statistic	Report Year: Baseline 1975-76	1977	1978	1979	1980
SPG-04	Flow	Maximum	..	..	..	94	230
		Minimum	..	..	..	..	260
	Temperature	Maximum	..	..	..	10.5	15.0
		Minimum	..	..	..	..	3.0
	Specific Conductance	Maximum	..	..	..	1000	1300
		Minimum	..	..	..	..	1000
	pH	Maximum	..	..	..	9.0	8.2
		Minimum	..	..	..	..	7.8
SPG-05	Flow	Maximum	..	..	..	75	1410
		Minimum	..	..	..	..	..
	Temperature	Maximum	22	..	..	11	13.8
		Minimum	3	..	..	6	1.2
	Specific Conductance	Maximum	1500	..	..	1600	1400
		Minimum	1300	..	..	1280	..
	pH	Maximum	..	..	..	8.0	8.2
		Minimum	..	..	..	7.0	7.7
SPG-08	Flow	Maximum	..	21	112	130	350
		Minimum	..	..	9	..	35
	Temperature	Maximum	12	10.5	12	7.7	9.9
		Minimum	5	..	4	..	5.5
	Specific Conductance	Maximum	1100	1140	1200	850	1140
		Minimum	850	..	1000	..	900
	pH	Maximum	..	..	7.0	7.7	7.9
		Minimum	..	..	6.8	..	7.4

Table 5-10. (Continued)

Station	Parameter[1]	Statistic	Report Year: Baseline 1975-76	1977	1978	1979	1980
SPG-14[2]	Flow	Maximum	..	19	69	2	3
		Minimum	..	..	14	..	3
	Temperature	Maximum	19	3.5	12	12	22
		Minimum	..	..	2.5	6.6	1.0
	Specific Conductance	Maximum	2000	1750	1700	2700	3760
		Minimum	1550	..	875	2000	2250
	pH	Maximum	..	..	7.8	8.0	8.2
		Minimum	..	..	7.0	7.7	7.8
SPG-20[3]	Temperature		..	..	..	..	10.0
	Specific Conductance		..	..	..	..	1110
	pH		..	..	..	..	7.9

[1] Units: flow - gal/min; temperature - °C; specific conductance - µmhos/cm at 25°C; pH - pH units

[2] Spring 14 was disturbed by road construction in 1979

[3] Single observation, 10/24/80

Table 5-11. Erosion/Sedimentation Monitoring Sites

Station Label	Physical Description
YES-1A	Corral Gulch above GS-S25
YES-3	Corral Gulch at GS-S25
YES-4	Corral Gulch above confluence with Dry Fork
YES-5	Corral Gulch below confluence with Dry Fork
YES-6	Corral Gulch 0.3 mile below confluence with Dry Fork
YES-7	Corral Gulch at GS-S27
YES-8	Corral Gulch at USGS Gage D
YES-9	Corral Gulch at GS-S11
YES-10	Corral Gulch at GS-S24
YES-11	Corral Gulch at Highway 24

5.2 GROUNDWATER

A. Alluvial Aquifers

1. Objectives

Alluvial aquifers on and near Tract C-a are monitored to identify and measure changes in water levels and water quality. Observed changes are evaluated as to their significance and causes and are examined relative to lease and permit requirements.

2. Methods

An array of 23 monitor wells is included in the alluvial aquifer program (Table 5-12). The program includes measurement of water level using steel tape or electric sounder methods. Water quality samples are collected by bailing. Measurements of temperature, specific conductance, and pH are made at the time of sample collection using field instruments. On a monthly, quarterly, or semiannual schedule (Table 5-12), samples are collected by bailing for extensive water chemistry analysis. Water chemistry analyses are listed in Table 5-13.

3. Results and Discussion

a. Physical Data - Physical data include measurements of water level, temperature, specific conductance, and pH. Physical data for the 1980 report year are summarized in Table 5-14 and compared to baseline (1975 and 1976) report year data.

Data for stations monitored during the baseline period (Table 5-14) indicate that pH and specific conductance have increased since the baseline period. The pH has generally changed from slightly acidic (<7) to slightly alkaline (>7). This is reflected in both mean and maximum values.

Table 5-12. Alluvial Well Monitoring Program, Tract C-a, Report Year 1980

Well	Sampling Program				
	Daily	Weekly	Monthly	Quarterly	Semiannually
GS-S7	WL[1/]	FWQ[2/]	WQ-A[3/]		WQ-B[4/]
GS-S11	WL	FWQ		WQ-A	WQ-B
GS-S11A	WL			WQ-A	
GS-S27	WL	FWQ	WQ-A		WQ-B
GS-S27A	WL				
GS-S26	WL		WQ-A		WQ-B
GS-S24	WL		FWQ	WQ-A	
Stake Springs		FWQ			
GS-S6			WQ-A		WQ-B
GS-S28S			FWQ		
GS-S28D			FWQ		
GS-28AS			FWQ		
GS-28AD			FWQ		
GS-29S			FWQ		
GS-29D			FWQ		
GS-S29AS			FWQ		
GS-S29AD			FWQ		
GS-S30			FWQ		
GS-S30A			FWQ		
GS-S8			WQ-A		WQ-B
GS-S13			WQ-A		WQ-B
GS-S14			WQ-A		WQ-B
GS-S25			WQ-A		WQ-B

1/ WL: water level

2/ FWQ: field water quality - specific conductance, temperature, pH, water level

3/ WQ-A: water quality grab samples - constituents on List A, Table 5-13

4/ WQ-B: water quality grab samples - constituents on List B, Table 5-13

Table 5-13. Water Chemistry Analysis, Groundwater Monitoring Program, Tract C-a, Report Year 1980

A (or Major A)		B (or Baseline Major)	
Total Alkalinity	Major A plus:		
Bicarbonate	Aluminum	Lithium	COD
Carbonate	Arsenic	Manganese	Color
Sulfate	Barium	Mercury	Specific Conductance
Silica (SiO_2)	Beryllium	Molybdenum	Cyanide
Chloride	Bismuth	Nickel	Total Dissolved Solids
Calcium	Bromide	Selenium	Odor
Magnesium	Cadmium	Strontium	pH
Hardness	Chromium	Titanium	Phenols
Potassium	Copper	Vanadium	Gross Alpha
Sodium	Gallium	Zinc	Gross Beta
Phosphorus	Germanium	Zirconium	Sulfide
Ammonia-N	Lead		Temperature
Nitrate-N			
Nitrite-N			
Fluoride			
Iron			
Boron			
DOC			

Table 5-14. Summary of 1980 Report Year Alluvial Well Physical Data and Comparison With Baseline Data, Tract C-a

Well	Parameter[1]	1980 Mean[3] ≥1975	1980 Mean[3] ≥1976	1980 Minimum[3] ≤1975	1980 Minimum[3] ≤1976	1980 Maximum[3] ≥1975	1980 Maximum[3] ≥1976
GS-S7	Temperature	..	9.3/8.3	6.7/8.4	..	13.8/12.3	13.8/11.1
	pH	7.5/6.5	7.5/6.3	..	..	7.9/6.8	7.9/6.6
	Water Level	23.4/23.0	23.4/22.9	16.3/20.7	..	Dry/25.5	Dry/34.6
	Conductivity	1206/1107	1206/1184	..	1000/1040	..	..
GS-S8[2]	Temperature	..	..	..	..	..	..
	pH	..	..	..	..	7.2/7	7.2/6.8
	Water Level	38.6/33.6	38.6/36.0	37.1/24.9	37.1/29.0	39.7/39.1	39.7/38.4
	Conductivity	..	..	..	..	..	..
GS-S11D	Temperature	..	10.0/9.4	6.9/8.0	..	..	13/11.7
	pH	7.5/6.5	7.5/6.4	..	..	7.9/7.2	7.9/6.8
	Water Level	..	..	..	..	Dry/48.4	Dry/45.5
	Conductivity	2800/1854	2800/1768	..	..	5510/2251	5510/2050
GS-S24	Temperature	..	..	5.1/8.1	5.1/6.8	14/11.3	14/11.1
	pH	7.6/6.6	7.6/6.4	..	..	8/7	8/6.6
	Water Level	7.7/6.8	7.7/7.5	5.2/5.2	5.2/6.2	8.9/8.1	..
	Conductivity	1697/1631	1697/1619	..	..	..	1900/1770

[1] Units: temperature - °C; pH - pH units; conductivity - µmhos/cm at 25°C; water level - depth to water (ft)

[2] Only single observations for 1980 for temperature, pH, and conductivity

[3] Where 1980 mean or maximum value equals or exceeds 1975 or 1976 value the data are listed as 1980 value/1975 value or 1980 value/1976 value. Unless otherwise indicated, the .. indicates that the 1980 value was less than the baseline year value.

Well GS-S7 is in Corral Gulch near the west boundary of Tract C-a and, thus, data collected here reflect water entering the Tract and not affected by development. The 1979 year-end report noted a cycle of rising water levels, temperature, and conductivity and lowering of pH beginning in April. This illustrates the natural runoff-recharge cycle. The 1980 report year data show a similar pattern of rise in water level in April through May, followed by a general decline from June through November 1980 (Figure 5-1). Seasonal cycles for temperature, conductivity, and pH were not as apparent at GS-S7 (Figures 5-2 through 5-4).

Well GS-S27 is in Corral Gulch near the east boundary and, thus, data reflect water leaving Tract C-a. During the 1980 report year, water levels rose steadily from late 1979 through May 1980 and then declined slowly through November 1980 (Figure 5-5). Temperature followed a similar cycle (Figure 5-6). This is contrasted to a general declining trend in water level noted in the 1979 year-end report. Conductivity at GS-S27 was variable during 1980 with peak levels in late 1979 and in August and September 1980 (Figure 5-7). GS-S27 pH data displayed no clear seasonal pattern (Figure 5-8).

Well GS-S24 is in Corral Gulch about 3 miles downstream from the eastern Tract boundary. During the 1980 report year, water levels declined from November 1979 through May 1980 (Figure 5-9). During June, the water level rose to the year peak in early July and then declined steadily through the end of the report year. This is probably a response to the natural runoff-recharge cycle and is similar to the pattern observed during 1979. Temperature at GS-S24 showed a pattern similar to the water level seasonal cycle (Figure 5-10). A seasonal pattern was not obvious for conductivity data (Figure 5-11). GS-S24 pH levels peaked early in 1980 and declined thereafter (Figure 5-12). No pH or temperature cycles were noted during the 1979 report year.

MANOVA of the differences between report years 1977 through 1980 was performed (Table 5-15). This analysis also showed significant differences in pH and specific conductance. Conductivity observed in recent years (1978 through

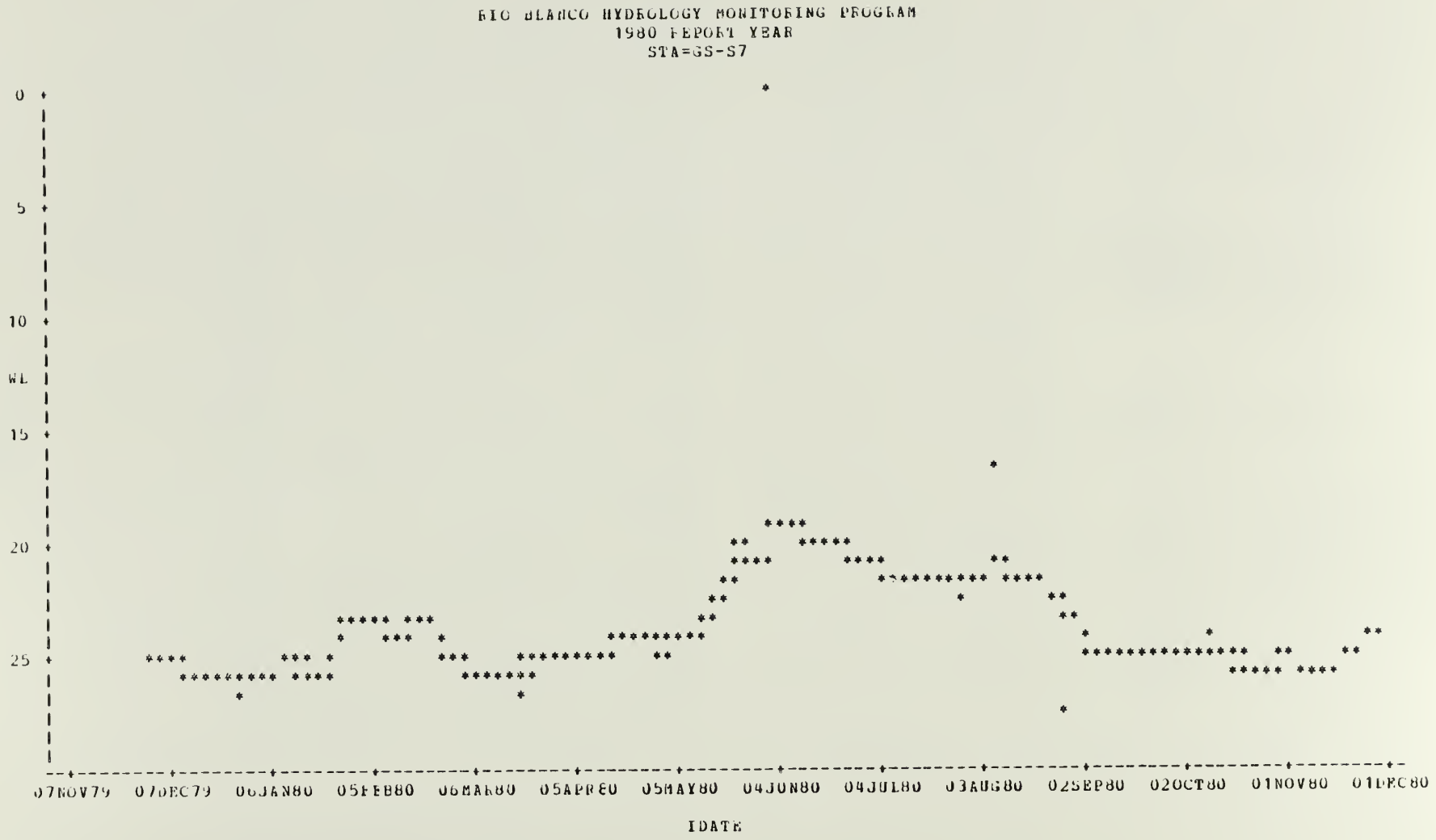


Figure 5-1. 1980 Report Year Water Level (WL depth to water in feet) Data, Well GS-S7, Tract C-a

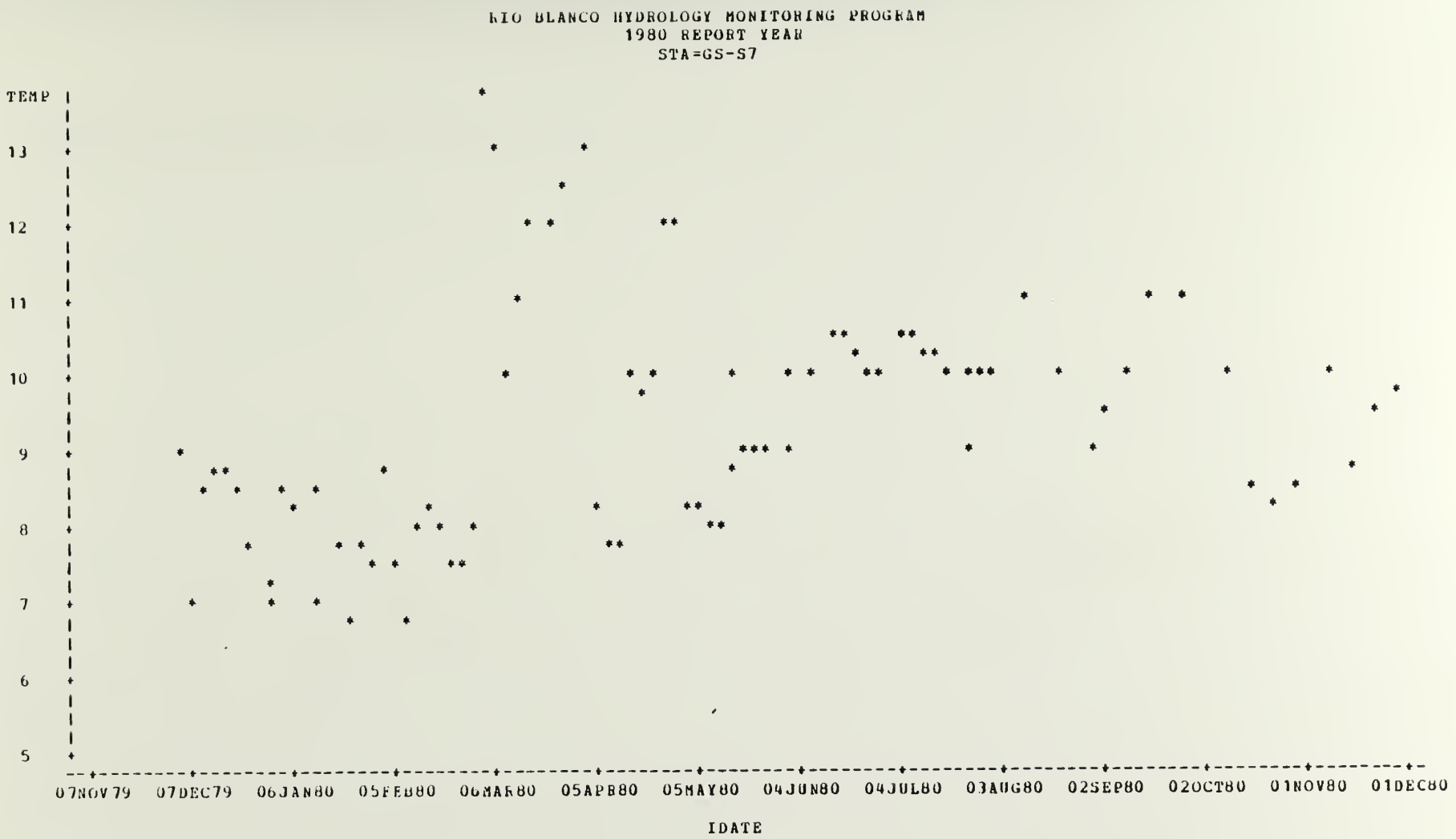


Figure 5-2. 1980 Report Year Water Temperature (TEMP, °C) Data, Well GS-S7, Tract C-a

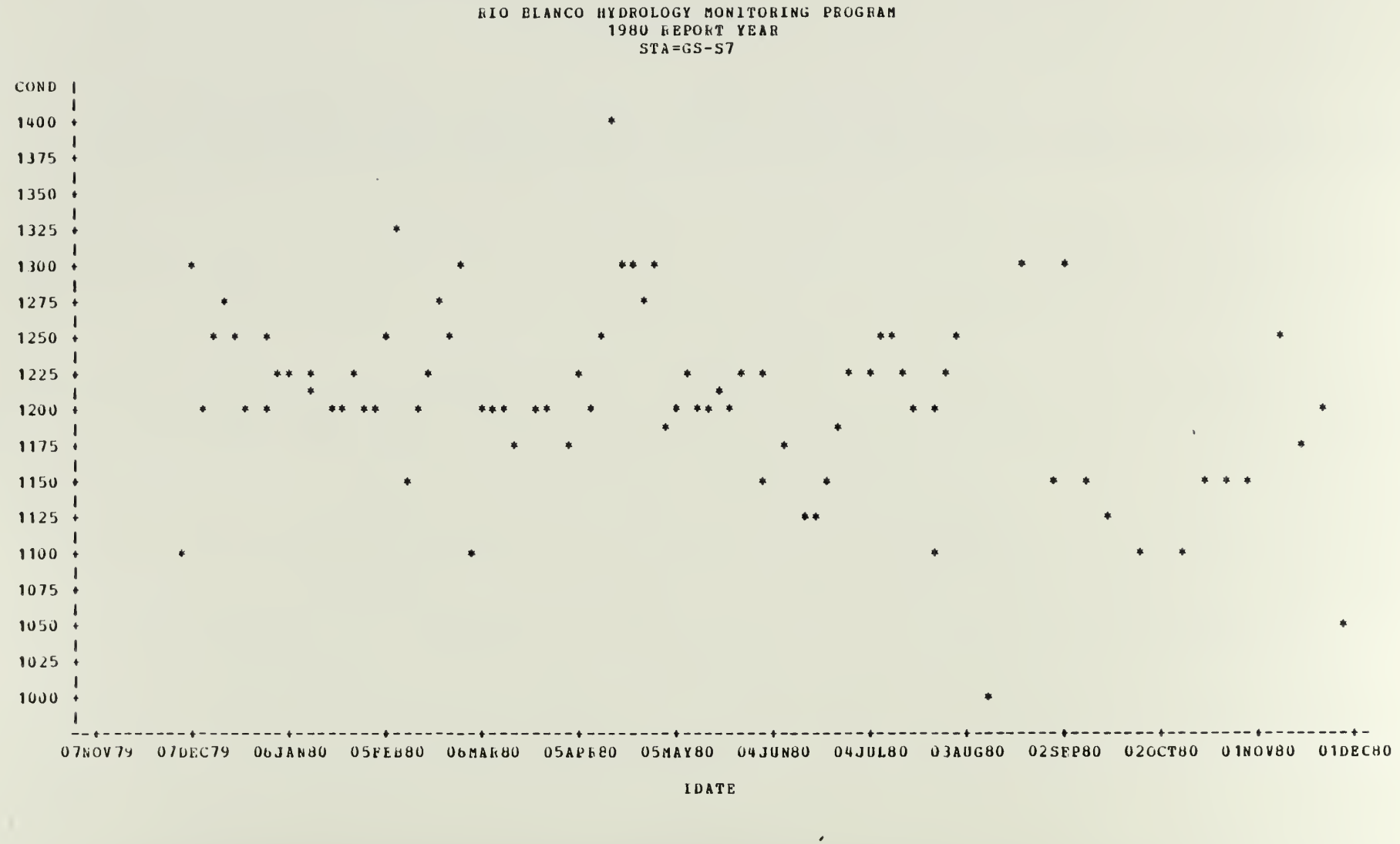


Figure 5-3. 1980 Report Year Specific Conductance (COND, µmhos/cm at 25°C) Data, Well GS-S7, Tract C-a

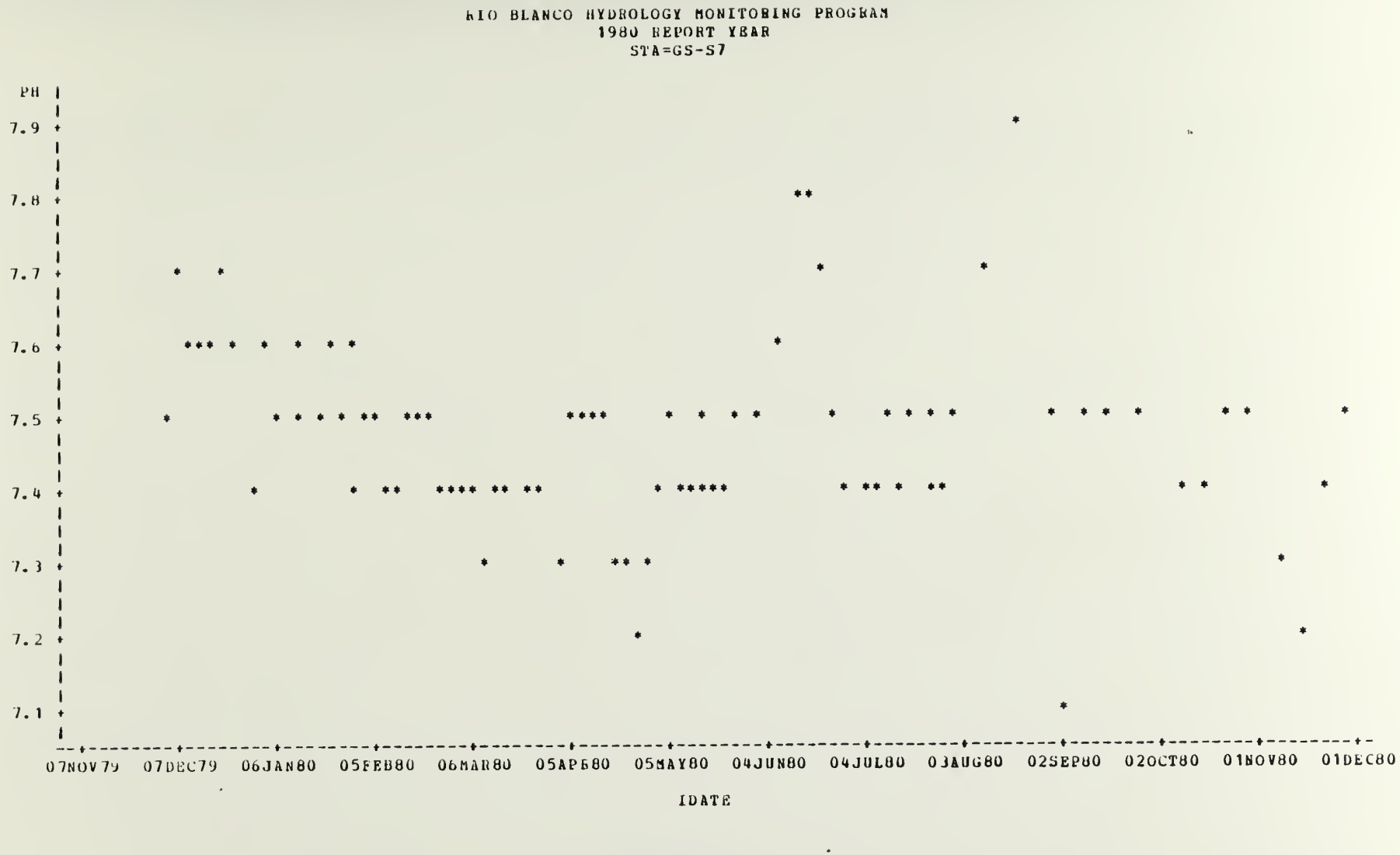


Figure 5-4. 1980 Report Year pH (pH units) Data, Well GS-S7, Tract C-a

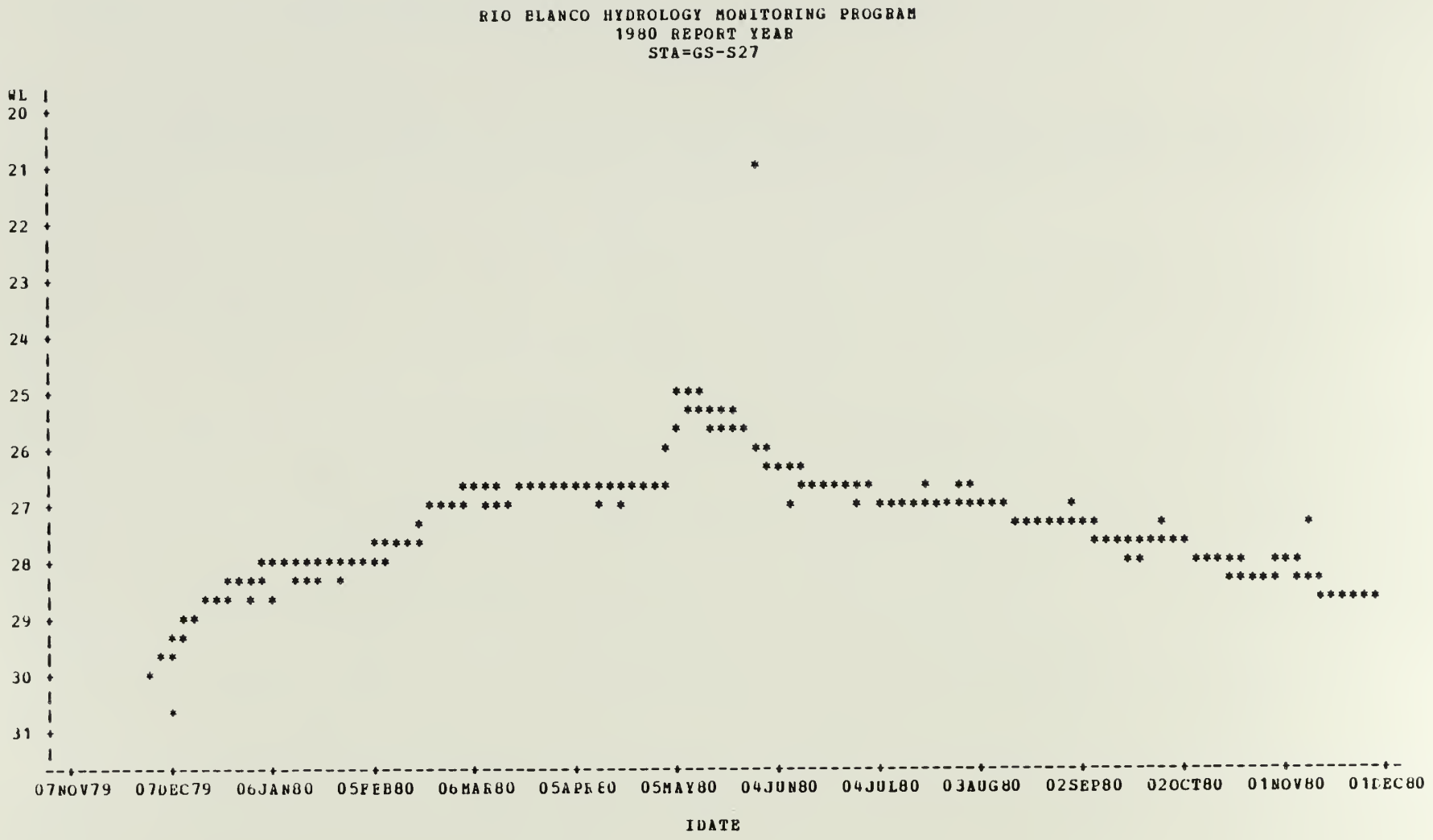


Figure 5-5. 1980 Report Year Water Level (WL depth to water in feet) Data, Well GS-S27, Tract C-a

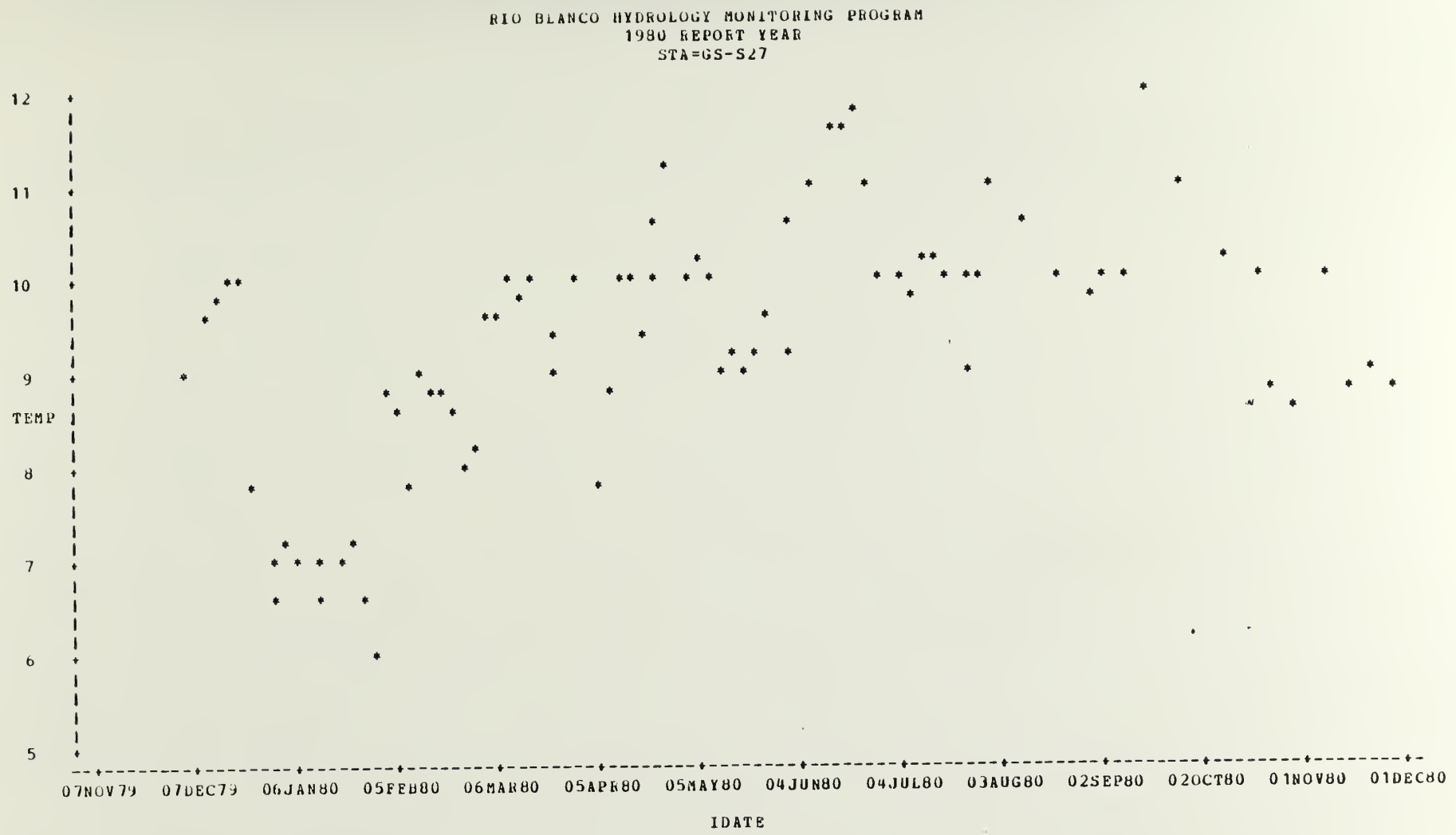


Figure 5-6. 1980 Report Year Water Temperature (TEMP, °C) Data, Well GS-S27, Tract C-a

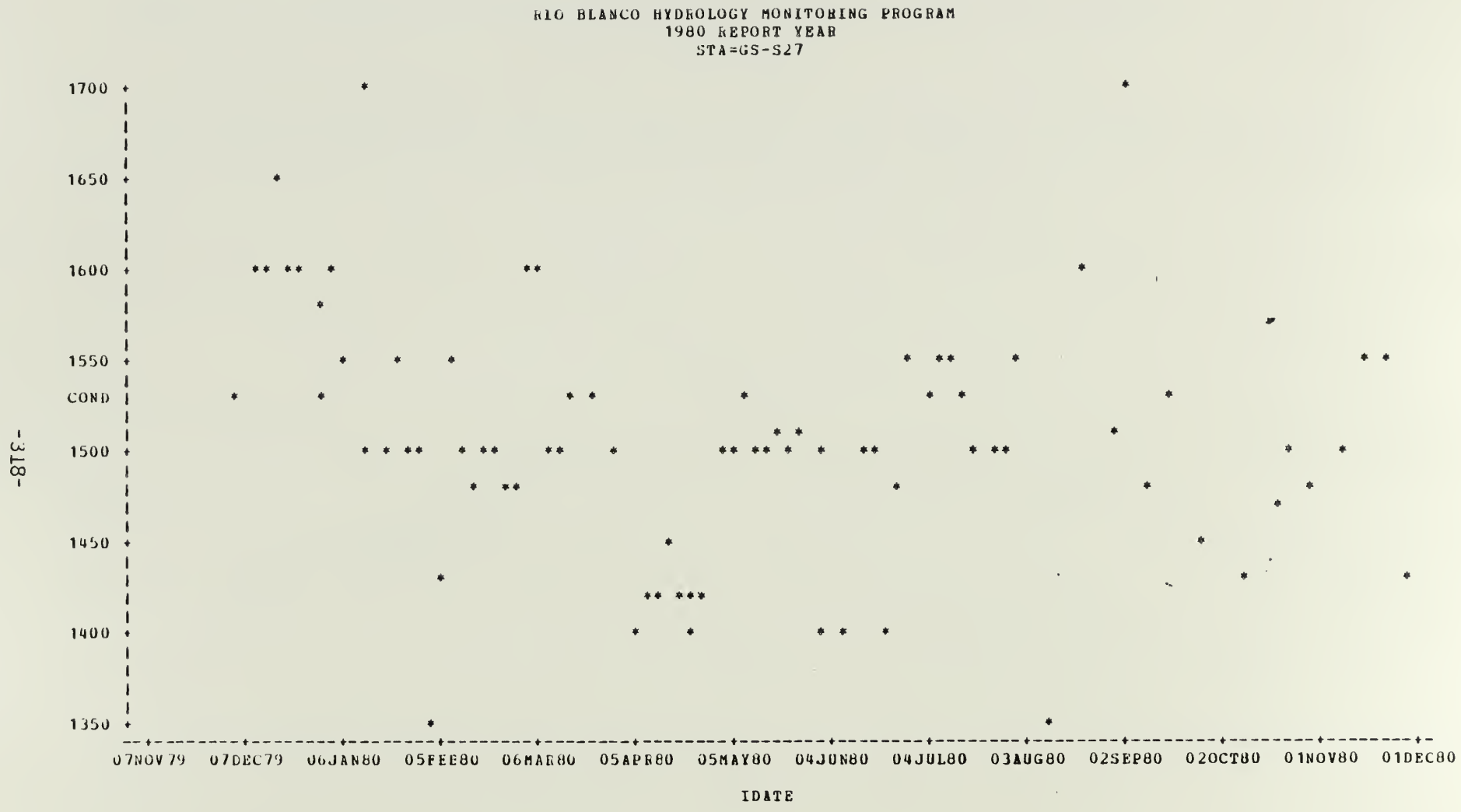


Figure 5-7. 1980 Report Year Specific Conductance (COND, µmhos/cm at 25°C) Data, Well GS-S27, Tract C-a

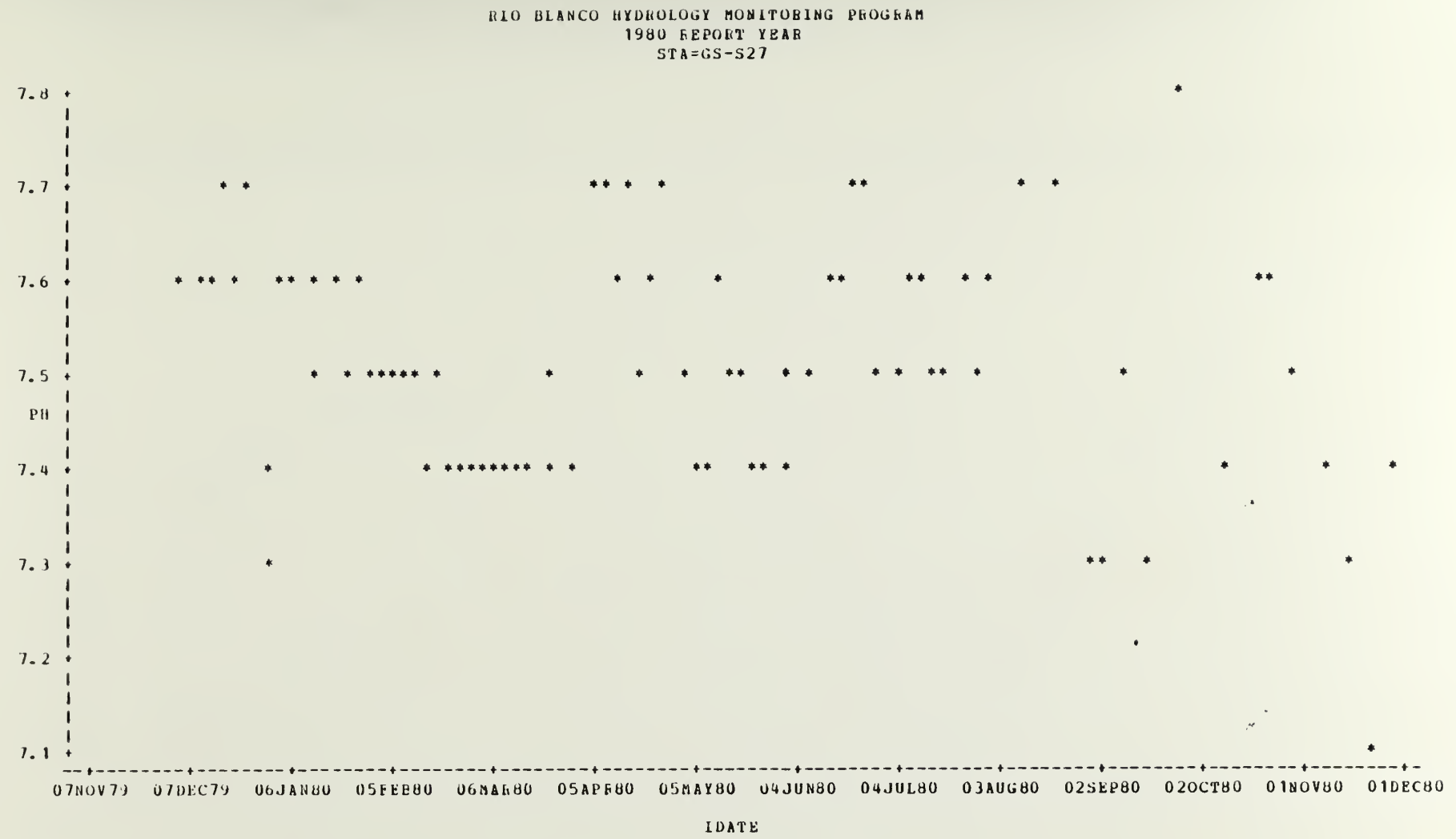


Figure 5-8. 1980 Report Year pH (pH units) Data, Well GS-S27, Tract C-a

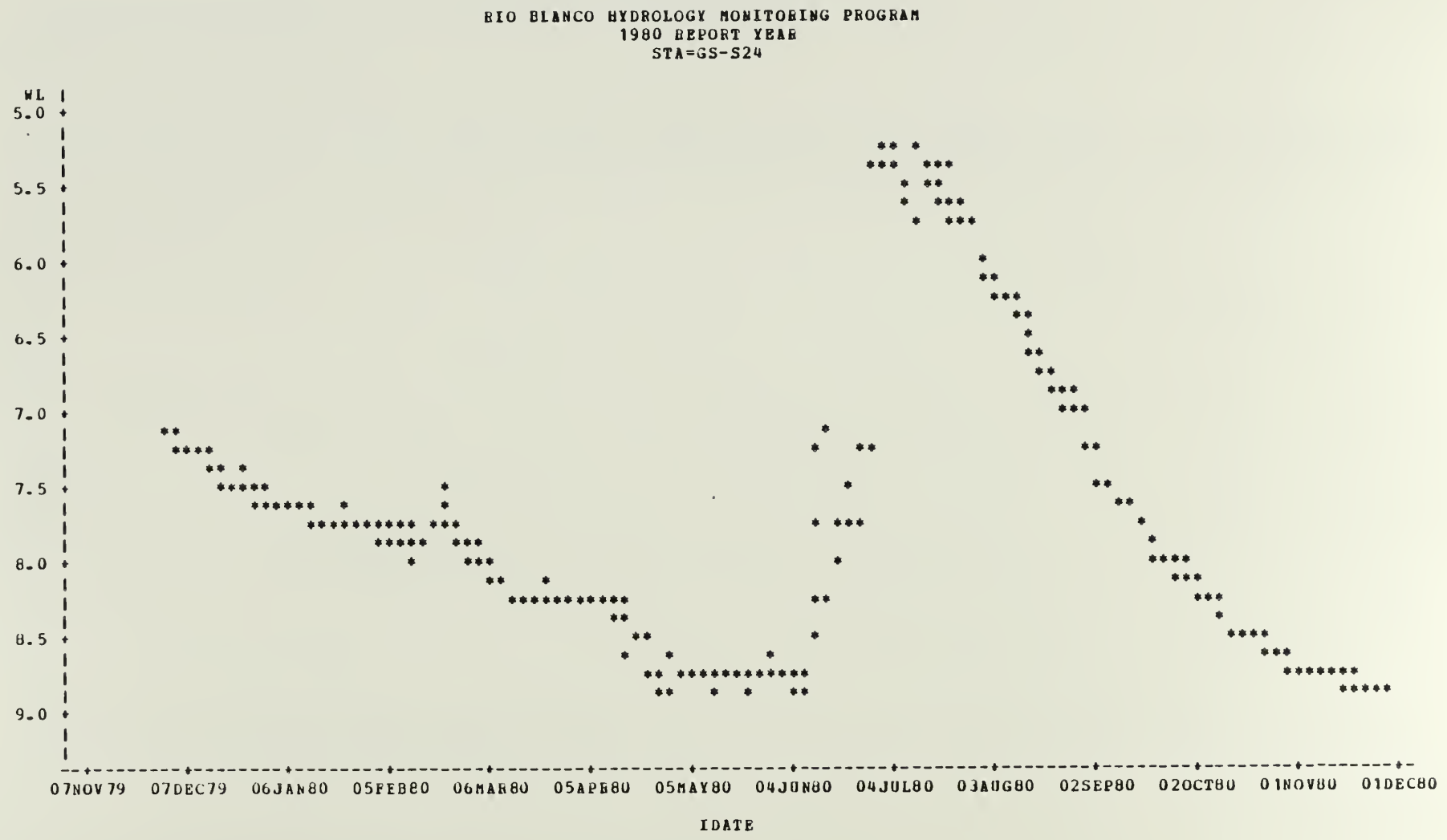


Figure 5-9. 1980 Report Year Water Level (WL depth to water in feet) Data, Well GS-S24, Tract C-a

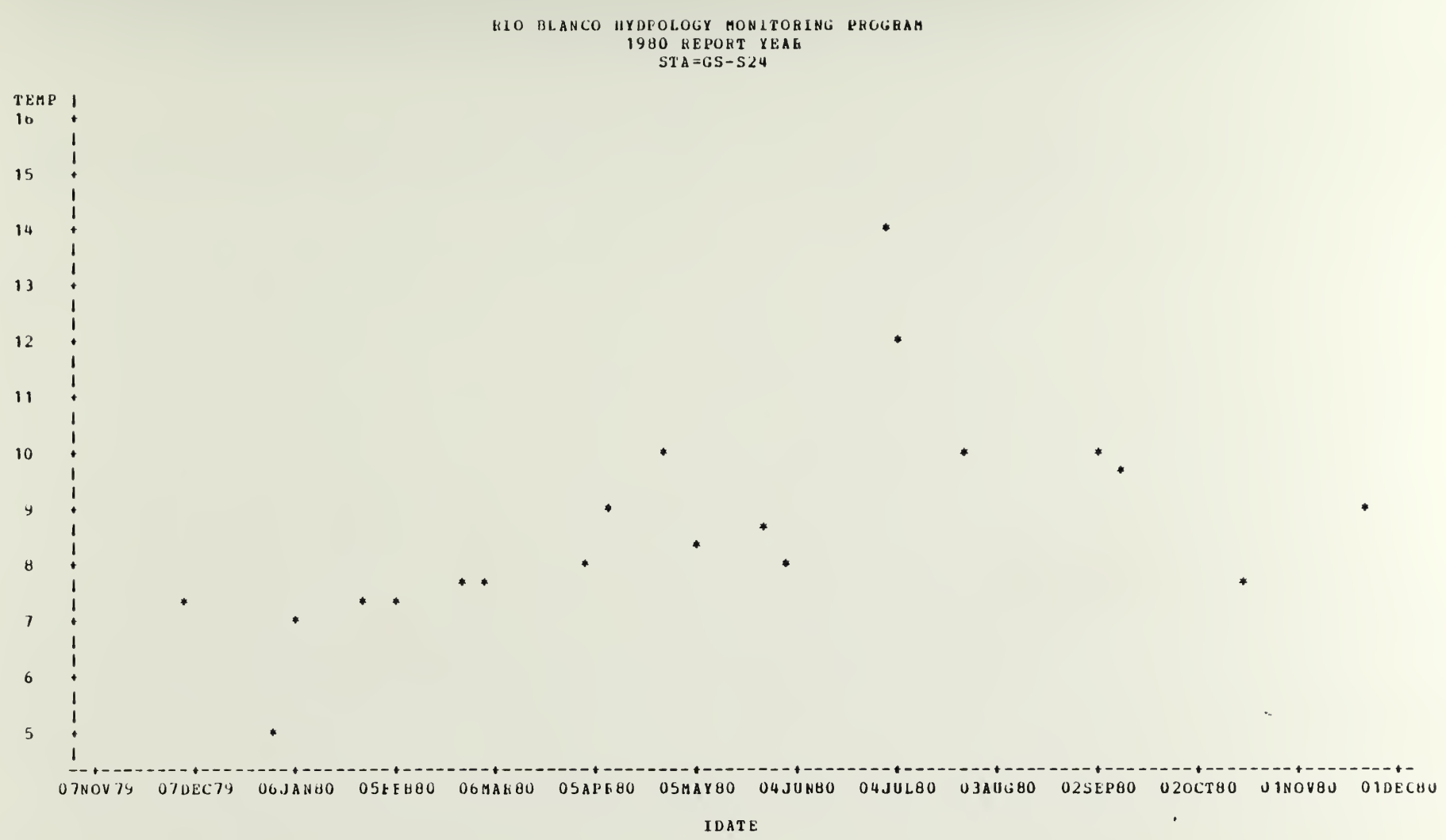


Figure 5-10. 1980 Report Year Water Temperature (TEMP, °C) Data, Well GS-S24, Tract C-a

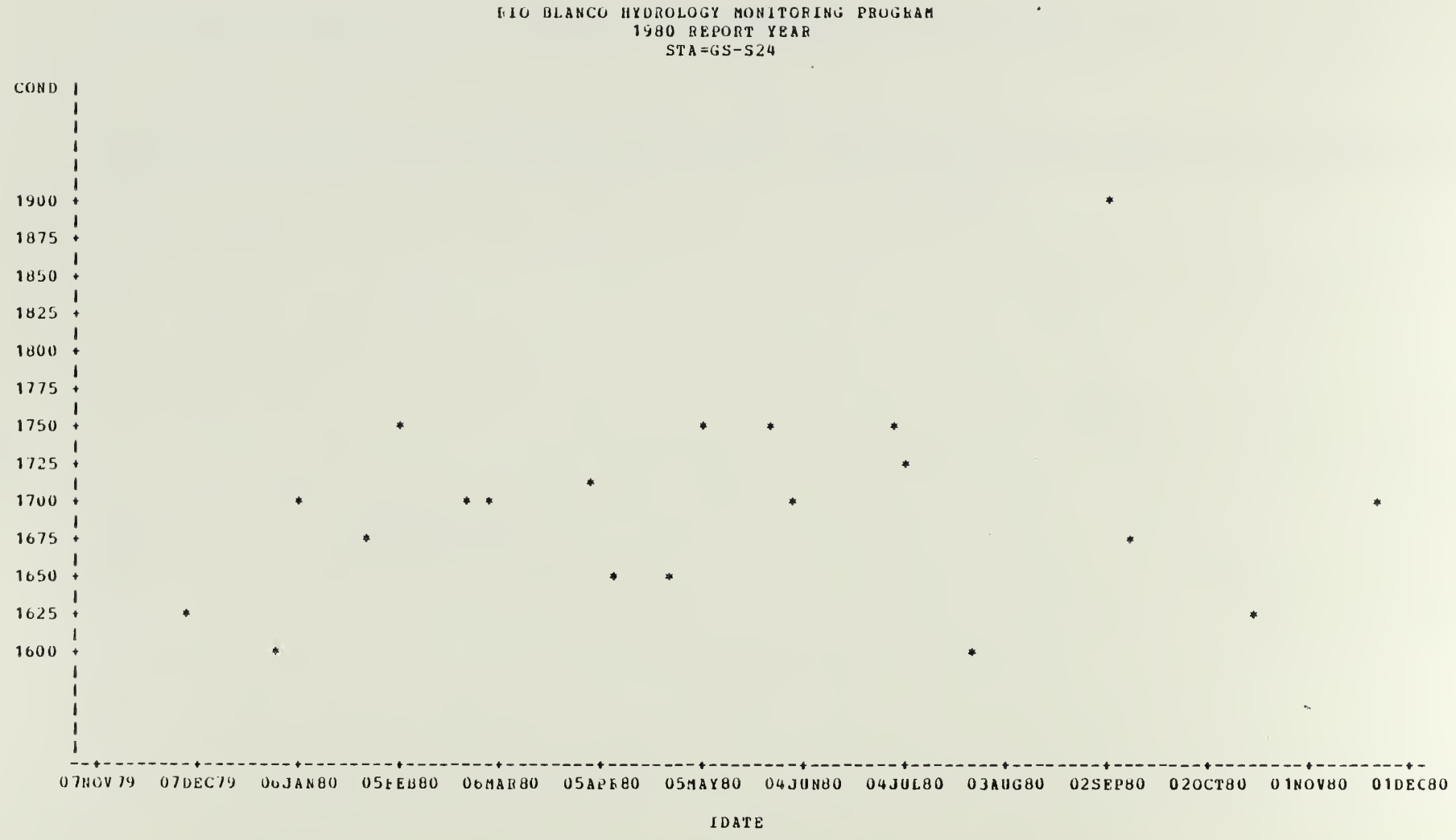


Figure 5-11. 1980 Report Year Specific Conductance (COND, µmhos/cm at 25°C), Data, Well GS-S24, Tract C-a

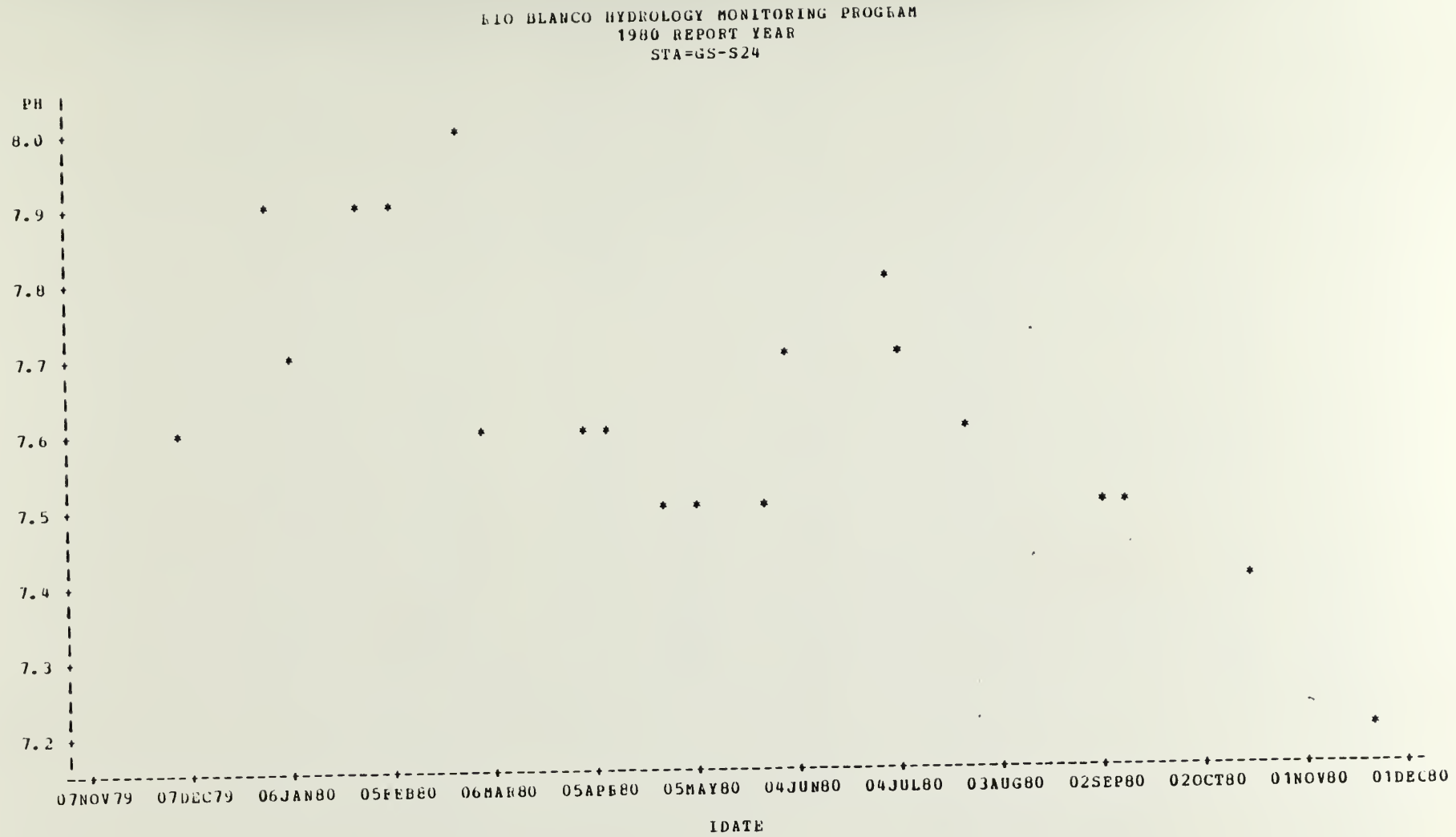


Figure 5-12. 1980 Report Year pH (pH units) Data, Well GS-S24, Tract C-a

1980) however showed no significant differences between report years. The pH values showed the following trend:

Report Year	n	Mean pH
1979	419	7.6
1980	327	7.5
1978	262	7.2
1977	17	6.9

These data show a continuation of the increasing trend in pH observed since the baseline. However, the overall mean pH for 1980 was lower than that observed for the 1979 report year. The 1980 physical data are presented in Appendix 5-2.1.

Table 5-15. Summary of MANOVA of Differences in Physical Parameters Over Period 1977 Through 1980, Tract C-a Alluvial Wells (Duncan's test results show years significantly different from 1980 report year)

	MANOVA Results		Duncan's Test
Variable	Pr > F[1/]	Significant[2/]	Report Years Significantly Different From 1980
pH	0.001	*	1977, 1978, 1979
Temperature	0.0713		
Conductivity	0.0164	*	1977

1/ Pr > F: probability of greater F value; if Pr > F is small (e.g. <0.05), it indicates significance

2/ At 5% level

This trend in pH is probably due to several factors including natural variability, sampling errors, and the discharge of upper aquifer water into the alluvial system. The presently observed slightly alkaline conditions are characteristic of western arid regions and the overall magnitude of the change is small. Thus natural variability and sampling are the most likely causes of this trend.

b. Water Quality Data - Alluvial water quality data for the 1980 report year are tabulated in Appendix 5-2.2. Alluvial wells for which data were collected are as follows:

- GS-S11D
- GS-S11DS
- GS-S27
- GS-S28AS
- GS-S28D
- GS-S28S
- GS-S29AS
- GS-S29D
- GS-S7
- GS-S8

These water quality data were evaluated in two ways. Means and maxima for the 1980 report year were compared to means and maximum values for the baseline report years 1975 and 1976. In addition, MANOVA was performed on data for selected chemical constituents to evaluate differences between report years. For this report, these data evaluations have been focused on major inorganic ions, selected trace elements, and general water quality measures.

The results of comparison of means and maximum observations are shown in Tables 5-16 through 5-19 for Stations GS-S7, GS-S8, GS-S27, and GS-S11D, respectively. Other alluvial wells sampled during the 1980 report year were sampled once or twice. These data are compared, where possible, to previously observed ranges in Table 5-20. Wells GS-S28S, GS-S28AS, and GS-S29AS were sampled for the first time during the 1980 report year.

The water quality comparisons (Tables 5-16 through 5-20) show general increases in pH and conductivity since the baseline period. This trend is not as evident at Well GS-S27 as at GS-S7 and GS-S8. The concentrations of major inorganic constituents are comparable for the most part with previous observations. Chloride and sulfate concentrations are elevated somewhat as are alkalinity and bicarbonate levels. Data for Wells GS-S11DS, GS-S28D, and GS-S29D show concentrations generally comparable or lower than 1979 observations.

Table 5-16. General Comparison of Water Quality, Alluvial Well GS-S7, Tract C-a, Report Year 1980, With Observations for Baseline (1975 and 1976) (data listed show 1980 means or maximum values which exceeded 1975 or 1976 data)

	GS-S7			
	1980 Mean[5]		1980 Maximum[5]	
Constituent[1]	≥1975	≥1976	≥1975	≥1976
Specific Conductance	1210/1107	1210/1184	..	..
pH	7.6/6.5	7.6/6.3	7.8/6.8	7.8/6.6
Alkalinity	396/377	396/356	440/400	440/400
HCO_3	462/445	462/432	505/490	505/490
Ca	100/99	100/93	..	..
Mg	64/45	64/51	..	70/67
Na	..	..	..	..
K[2]	..	..	..	..
Cl	16.3/10.7	16.3/8.7	27.5/17	27.5/20
SO_4	325/269	325/306	354/330	354/350
F	..	0.34/0.30	..	0.46/0.40
As[3]	..	..	..	..
Mo[4]	..	..	..	..
V[4]	..	..	..	..
Se[3]	..	..	..	..
Hg[3]	..	..	..	..
DOC	..	..	..	..
TDS	875/813	875/806	..	..
SiO_2	..	..	..	..
B	..	..	..	..

[1] Units: specific conductance - μmhos/cm at 25°C; pH - pH units; others - mg/l

[2] No 1975 data

[3] One 1980 observation, As < 0.01 mg/l, Se < 0.01 mg/l, Hg < 0.001 mg/l

[4] No 1980 data

[5] Where 1980 mean or maximum value equals or exceeds 1975 or 1976 value the data are listed as 1980 value/1975 value or 1980 value/1976 value. Unless otherwise indicated, the .. indicates that the 1980 value was less than the baseline year value.

Table 5-17. General Comparison of Water Quality, Alluvial Well GS-S8, Tract C-a, Report Year 1980, With Observations for Baseline (1975 and 1976) (data listed show 1980 means or maximum values which exceeded 1975 or 1976 data)

	GS-S8			
	1980 Mean[5]		1980 Maximum[5]	
Constituent[1]	≥1975	≥1976	≥1975	≥1976
Specific Conductance	..	..	..	..
pH	7.5/6.5	7.5/6.3	7.9/7.0	7.9/6.8
Alkalinity	..	..	..	..
HCO_3	..	430/426	..	479/465
Ca	..	..	..	97/92
Mg	57/43	57/49	71/70	71/70
Na	..	..	..	..
K[2]	..	..	..	..
Cl	..	..	..	..
SO_4	..	..	260/230	260/235
F	..	0.35/0.26	..	0.40/0.40
As[3]	..	..	..	..
Mo[4]	..	..	..	..
V[4]	..	..	..	..
Se[3]	..	..	..	..
Hg[3]	..	..	..	..
DOC	..	..	..	..
TDS	..	..	..	..
SiO_2	..	..	..	..
B	..	..	..	0.33/0.20

[1] Units: specific conductance - µmhos/cm at 25°C; pH - pH units; others - mg/l

[2] No 1975 data

[3] One 1980 observation, As < 0.01 mg/l, Se < 0.01 mg/l, Hg < 0.001 mg/l

[4] No 1980 data

[5] Where 1980 mean or maximum value equals or exceeds 1975 or 1976 value the data are listed as 1980 value/1975 value or 1980 value/1976 value. Unless otherwise indicated, the .. indicates that the 1980 value was less than the baseline year value.

Table 5-18. General Comparison of Water Quality, Alluvial Well GS-S27, Tract C-a, Report Year 1980, With Observations for Baseline (1975 and 1976) (data listed show 1980 means or maximum values which exceeded 1975 or 1976 data)

	GS-S27			
	1980 Mean[4]		1980 Maximum[4]	
Constituent[1]	≥1975	≥1976	≥1975	≥1976
Specific Conductance	1551/1477	..	1715/1680	..
pH	7.6/7.2	7.6/7.7	..	..
Alkalinity	494/473	494/459	546/500	546/490
HCO_3	582/548	582/563	645/610	645/600
Ca	106/94	106/100	123/120	..
Mg	95/86	95/78	..	104/94
Na	..	..	..	..
K	..	..	3.3/3.3	..
Cl	..	..	23/5/22.0	..
SO_4	..	417/388	503/495	..
F	0.27/0.25	0.27/0.26	..	..
As[2]	..	..	..	..
Mo[3]	..	..	..	..
V[3]	..	..	..	..
Se[2]	..	..	..	..
Hg[2]	..	..	..	..
DOC	..	..	..	..
TDS	..	..	1220/990	1220/1180
SiO_2	19.9/13.2	19.9/18.3	26/20	26/23
B	..	0.30/0.18	..	0.69/0.30

[1] Units: specific conductance - µmhos/cm at 25°C; pH - pH units; others - mg/l

[2] No 1975 data

[3] One 1980 observation, As < 0.01 mg/l, Se < 0.01 mg/l, Hg < 0.001 mg/l

[4] Where 1980 mean or maximum value equals or exceeds 1975 or 1976 value the data are listed as 1980 value/1975 value or 1980 value/1976 value. Unless otherwise indicated, the .. indicates that the 1980 value was less than the baseline year value.

Table 5-19. General Comparison of Water Quality, Alluvial Well GS-S11D, Tract C-a, Report Year 1980, With Observations for Baseline (1975 and 1976) (data listed show 1980 means or maximum values which exceeded 1975 or 1976 data)

	GS-S11D			
	1980 Mean[5]		1980 Maximum[5]	
Constituent[1]	≥1975	≥1976	≥1975	≥1976
Specific Conductance	[2]		2600/2250	2600/2050
pH	..	..	7.9/7.2	7.9/6.8
Alkalinity	..	..	..	..
HCO_3	..	..	..	..
Ca	..	..	..	..
Mg	..	..	..	123/115
Na	..	..	361/300	361/350
K[3]	..	..	..	..
Cl	..	..	..	..
SO_4	..	..	914/720	914/700
F	..	..	..	0.34/0.30
As[4]	..	..	..	..
Mo[4]	..	..	..	..
V[4]	..	..	..	..
Se[4]	..	..	..	..
Hg[4]	..	..	..	..
DOC	..	..	..	45/42
TDS	..	..	1916/1640	1916/1650
B	..	..	..	..

[1] Units: specific conductance - μmhos/cm at 25°C; pH - pH units; others - mg/l

[2] Only one or two 1980 samples, thus only maximum values compared

[3] No 1975 data

[4] No 1980 data

[5] Where 1980 mean or maximum value equals or exceeds 1975 or 1976 value the data are listed as 1980 value/1975 value or 1980 value/1976 value. Unless otherwise indicated, the .. indicates that the 1980 value was less than the baseline year value.

Table 5-20. Comparison of 1980 Report Year Alluvial Water Quality Data With Previously Observed (1979 Report Year) Maximum Observations

Constituent[1/]	GS-S11DS		GS-S28D		GS-S29D	
	1980	1979	1980	1979	1980	1979
Specific Conductance	2000	2700	1900	..	4200	..
pH	7.6	7.5	7.9	..	7.5	..
Alkalinity	511	448	560	520	857	840
HCO_3	581	546	668	..	1012	..
CO_3	<0.01	<0.1	<0.01	..	<0.01	..
Ca	74	98	76	140	72	130
Mg	98	184	131	93	271	240
Na	260	190	204	280	650	800
K	6.8	4.5	5.6	..	3.3	..
Cl	17	41	19	58	38	200
SO_4	560	961	470	620	1710	1600
F	0.37	0.4	0.51	0.4	0.75	0.7
As	..	<0.01	..	..	..	..
B	0.22	0.20	0.15	..	0.54	..
Mo	..	..	..	..	..	..
V	..	..	..	..	..	..
Se	..	<0.01	..	..	..	..
Hg	..	<0.001	..	..	..	..
DOC	7.3	66	7.7	..	11	..
TDS	..	1000	..	..	..	..
SiO_2	24.5	33	24	22	15	22

[1/] Units: specific conductance - µmhos/cm at 25°C; pH - pH units; others - mg/l

The MANOVA results (Table 5-21) show significant differences for the main effect report year for most of the chemical constituents tested. In addition, the Duncan test results indicated that 1980 water quality data were significantly different from data collected during the baseline report years (1975 and 1976) for several constituents. However, with the exception of specific conductance, pH, and magnesium, the overall mean concentrations during the

baseline were greater than the mean concentrations for the 1980 report year. Report year means for these constituents for the alluvial wells are as follows:

	1975	1976	1977	1978	1979	1980
Specific Conductance	1520	1545	980	1285	1090	1895
pH	6.5	6.0	6.9	6.8	7.6	7.6
Magnesium	81.4	93.3	95.6	87.6	96.1	120.8

Table 5-21. Summary of MANOVA of Differences in Alluvial Water Quality Data Over 1975-1976 Report Years (Duncan's test results show years significantly different from 1980 report year)

Variable	MANOVA Results		Duncan Test
	Pr > F[1/]	Significant[2/]	Water Years Significantly Different From 1980
Temperature	0.0001	*	1975, 1976, 1977
Specific Conductance	0.0001	*	All previous years
pH	0.0001	*	1975, 1976
HCO_3	0.0001	*	1978, 1979
CO_3	0.0031	*	None
SO_4	0.1726		
Cl	0.0007	*	1979
Ca	0.0033	*	None
Mg	0.0145	*	All previous years
Na	0.8218		
K	0.0001	*	1979
F	0.0017	*	None
As	0.0001	*	1975, 1976
B	0.0003	*	1975
Se	0.0001	*	1975, 1976, 1977
Hg	0.0001	*	1975
DOC	0.0001	*	1975

[1/] Pr > F: probability of greater F value; if Pr > F is small (e.g. <0.05), it indicates significance

[2/] At 5% level

Similar results were noted in the 1979 year-end report with significant increases in specific conductance (and TDS) as well as several major inorganic ions. This was particularly true of Wells GS-S11 and GS-S27 and was concluded to show the influence of dewatering discharges.

B. Deep Oil Shale Aquifers (Upper and Lower)

1. Objectives

Deep (upper and lower) oil shale aquifers are monitored on and near Tract C-a to identify and measure changes in water level and water quality. Observed changes are evaluated as to their significance relative to baseline conditions and relation to oil shale development. In addition, the monitoring program results are examined relative to lease and permit requirements.

2. Methods

An array of 34 monitor wells is included in the deep aquifer monitoring program (Table 5-22). Twenty-seven of these are completed in the upper aquifer zone and seven are completed in the lower aquifer zone. Water levels are measured using an electric sounder. Water quality samples are collected by bailing. Measurements of temperature, specific conductance, and pH are made at the time of sample collection using field instruments. Constituents included in the extensive water quality analysis are listed in Table 5-13.

3. Results and Discussion

a. Physical Data - Physical data include measurements of water level, temperature, specific conductance, and pH. Data for the upper aquifer are summarized and compared to baseline (1975 and 1976) report years in Table 5-23. Mean values and ranges of the physical data have been compared.

Trends noted in these upper aquifer data summaries include increased pH levels and slightly increased conductivity levels since the baseline period. The pH

Table 5-22. Deep Aquifer (Upper and Lower Aquifer) Monitoring Program, Tract C-a, Report Year 1980

	Weekly	Monthly	Quarterly	Semiannually	Annually
Upper Aquifer:					
AM-3U	WL[1/]	WQ-A[2/]			WQ-B[3/]
GS-M1U	WL	WQ-A			WQ-B
GS-M2U	WL				WQ-B
GS-M3U	WL				WQ-B
GS-M4U	WL	WQ-A			WQ-B
GS-M6U	WL			WQ-B	
GS-M7U	WL			WQ-B	
GS-M8U	WL			WQ-B	
GS-M9U	WL			WQ-B	
GS-M10U	WL			WQ-B	
GS-M11U	WL			WQ-B	
GS-M12U	WL			WQ-B	
AM-2AU	WL			WQ-B	
GS-15U	WL	WQ-A			WQ-B
GS-9U	WL	WQ-A		WQ-B	
GS-10U	WL	WQ-A		WQ-B	
GS-1U	WL				
GS-12U	WL				
GS-13U	WL				
GS-2-3U	WL				
CE-701U	WL	WQ-A		WQ-B	
CE-702U	WL	WQ-A		WQ-B	
CE-705AU	WL	WQ-A		WQ-B	
CE-707U	WL	WQ-A		WQ-B	
CE-708U	WL				
CE-709U	WL	WQ-A		WQ-B	
GS-M5		WL			
Lower Aquifer:					
GS-15L	WL				WQ-B
CE-702L	WL				
CE-709L	WL		WQ-A		WQ-B
GS-17L	WL		WQ-A		WQ-B
GS-4-5L	WL		WQ-A		WQ-B
GS-19L	WL		WQ-A		WQ-B
GS-18L			WQ-A		WQ-B

1/ WL: water level

2/ WQ-A: water quality grab samples - constituents on List A, Table 5-13

3/ WQ-B: water quality grab samples - constituents on List B, Table 5-13

Table 5-23. Comparison of Physical Monitoring Data, Upper Aquifer, Tract C-a (report year 1980 is compared to baseline report years 1975 and 1976)

Well	Parameter[2]	1980 Mean[1/4] ≥1975	1980 Mean[1/4] ≥1976	1980 Minimum[1/4] ≤1975	1980 Minimum[1/4] ≤1976	1980 Maximum[1/4] ≥1975	1980 Maximum[1/4] ≥1976
AM-2AU	Temperature	..	..	..	..	..	..
	pH	..	..	..	..	7.8/7.0	7.8/7.0
	Water Level	..	..	374/388	374/378	..	..
	Conductivity	..	..	..	..	..	..
AM-3U	Temperature	..	..	..	..	..	11.8/9.4
	pH	..	..	..	..	8.3/7.3	8.3/6.9
	Water Level	..	..	28/33	28/29	..	..
	Conductivity	..	..	..	..	1100/1020	1100/1010
CE-701U[3]	Temperature	..	..	..	..	13/11.2	..
	pH	..	..	..	..	8.5/6	..
	Water Level	144/140	..	95/129	..	160/158	..
	Conductivity	..	..	..	..	1350/1120	..
CE-702U	Temperature	..	..	12.2/16.1	..	..	..
	pH	8.1/7.6	..	..	..	8.3/8.0	8.3/7.6
	Water Level	..	..	42/48	42/52	..	58/55
	Conductivity	..	..	..	..	..	..
CE-705AU[3]	Temperature	..	..	..	..	..	..
	pH	7.8/6.6	..	..	..	8.5/7.7	..
	Water Level	250/123	..	241/264	..	..	..
	Conductivity	..	..	910/1120	..	..	..
CE-707U	Temperature	..	..	9/11.1	..	..	11/10.6
	pH	7.8/6.5	..	..	..	8.2/6.8	8.2/6.6
	Water Level	..	..	225/259	225/250	..	..
	Conductivity	..	..	1250/1300	..	1650/1560	1650/1530

Table 5-23. (Continued)

Well	Parameter[2]	1980 Mean[1/4] ≥1975	1980 Mean[1/4] ≥1976	1980 Minimum[1/4] ≤1975	1980 Minimum[1/4] ≤1976	1980 Maximum[1/4] ≥1975	1980 Maximum[1/4] ≥1976
CE-708U	Water Level	..	50/49	40/46	40/44	60/54	60/52
CE-709U	Temperature	10.4/9.8	..	..	..	11.8/10.6	11.8/9.4
	pH	7.5/6.4	..	..	..	8/7	8/7.1
	Water Level	247/50	247/35	..	..	257/54	257/39
	Conductivity	1654/1269	..	..	..	1700/1541	1700/1200
GS-M1U	Temperature	..	..	11.8/13.2	..	15.6/15.1	15.6/14.3
	pH	7.9/6.7	..	..	..	8.3/7.0	8.3/6.8
	Water Level	647/634	647/620	602/621	602/619	656/645	656/626
	Conductivity	1329/1169	..	..	..	1400/1200	1400/1140
GS-M2U	Temperature	..	..	..	..	..	12.5/10.8
	pH	..	..	..	..	9.4/6.8	9.4/7.2
	Water Level	..	..	216/231	216/221	..	..
	Conductivity	..	..	..	..	..	..
GS-M3U	Temperature	..	..	..	..	12/11.1	12/11.2
	pH	..	..	..	..	9.7/7.2	9.7/6.5
	Water Level	..	..	11/21	11/18	..	..
	Conductivity	..	..	..	..	..	..
GS-M4U	Water Level	544/491	544/493	..	..	550/493	550/494
GS-1U	Water Level	..	..	224/244	224/242	..	..
GS-9U	Temperature	..	..	10.9/11.6	..	..	14/12.2
	pH	7.5/6.7	..	..	..	8.1/7	8.1/6.9
	Water Level	335/323	335/319	271/312	271/315	353/323	353/321
	Conductivity	..	..	820/1311	..	..	..
GS-12U	Water Level	..	..	374/388	374/382	..	..

Table 5-23. (Continued)

Well	Parameter[2]	1980 Mean[1/4] ≥1975	1980 Mean[1/4] ≥1976	1980 Minimum[1/4] ≤1975	1980 Minimum[1/4] ≤1976	1980 Maximum[1/4] ≥1975	1980 Maximum[1/4] ≥1976
GS-13U	Water Level	425/385	425/382	..	..	428/388	428/386
GS-10U	Temperature	13/12.8	13/12.9	..	..	13.8/13.6	..
	pH	7.6/6.5	..	..	..	8.5/6.8	8.5/6.8
	Water Level	432/341	432/340	..	..	441/343	441/342
	Conductivity	..	..	1950/2140	1950/1950	..	..
GS-15U	Temperature	..	..	..	..	..	13.8/13.6
	pH	..	..	..	..	..	8.2/7.3
	Water Level	307/275	307/273	..	..	309/279	309/275
	Conductivity	2200/1366	..	..	..	2350/1490	2350/1475
GS-2-3U	Water Level	220/115	220/100	..	..	231/121	231/102

1/ Where only one to three observations were made in 1980 or one of the other report years, only maximum values were compared

2/ Units: temperature - °C; pH - pH units; conductivity - µmhos/cm at 25°C; water level - depth to water, rounded to nearest foot

3/ No 1976 data

4/ Where 1980 mean or maximum value equals or exceeds 1975 or 1976 value the data are listed as 1980 value/1975 value or 1980 value/1976 value. Unless otherwise indicated, the .. indicates that the 1980 value was less than the baseline year value.

data for the upper aquifer indicate a rise from slightly less than 7 to greater than 8 and, in some cases (e.g., GS-M2U and GS-M3U), maximum values greater than 9 were observed during the 1980 report year. Mean pH values were for the most part in the 7.5 to 7.9 range during the 1980 report year. Maximum conductivity levels (maximum for the report year at a given well) were 100- to 300-µmhos/cm greater than maxima for the baseline report years at several locations (e.g., AM-3U, CE-701U, CE-707U, CE-709U, and GS-M1U). Conductivity at GS-15U showed an increase of about 900 µmhos/cm relative to the baseline levels while Wells CE-707U, GS-9U, and GS-10U exhibited some conductivity levels less than baseline minimum conductivity values at these locations.

In general, water levels were comparable to baseline data at most stations. Wells CE-705AU, CE-709U, GS-M4U, GS-13U, GS-10U, and GS-2-3U showed the effects of the dewatering activity on Tract C-a (Table 5-23). The 1980 upper aquifer physical data are presented in Appendix 5-2.3. The cone of depression from dewatering activities is shown in Figure 5-24 (under the discussion of development activities monitoring).

Hydrographs are presented here for several wells to show the various types of locations monitored. The major influences on the upper aquifer are the water level variations due to the mine dewatering/reinjection program. Well CE-701U showed a steady decline in water level through 1979 due to dewatering. However, this decline stabilized in late-1979 through mid-1980 and water levels then increased to pre-1979 levels from the effects of reinjection at TO-2U. (Figure 5-13). Water levels in CE-702U were increasing in the Fall of 1979 and this increase continued through May 1980 (Figure 5-14). Water levels in CE-702U then declined slightly through the end of the 1980 report year as reinjection in nearby TO-3U was reduced.

Well CE-709U is in close proximity to the mining activities on Tract C-a. Rapid and relatively large (10- to 15-foot) fluctuations in water level were noted during 1979 and were associated with mine dewatering, reinjection, and recharge through Corral Gulch. Water levels were declining at the end of 1979 and continued that decline through July 1980 (Figure 5-15). Water levels

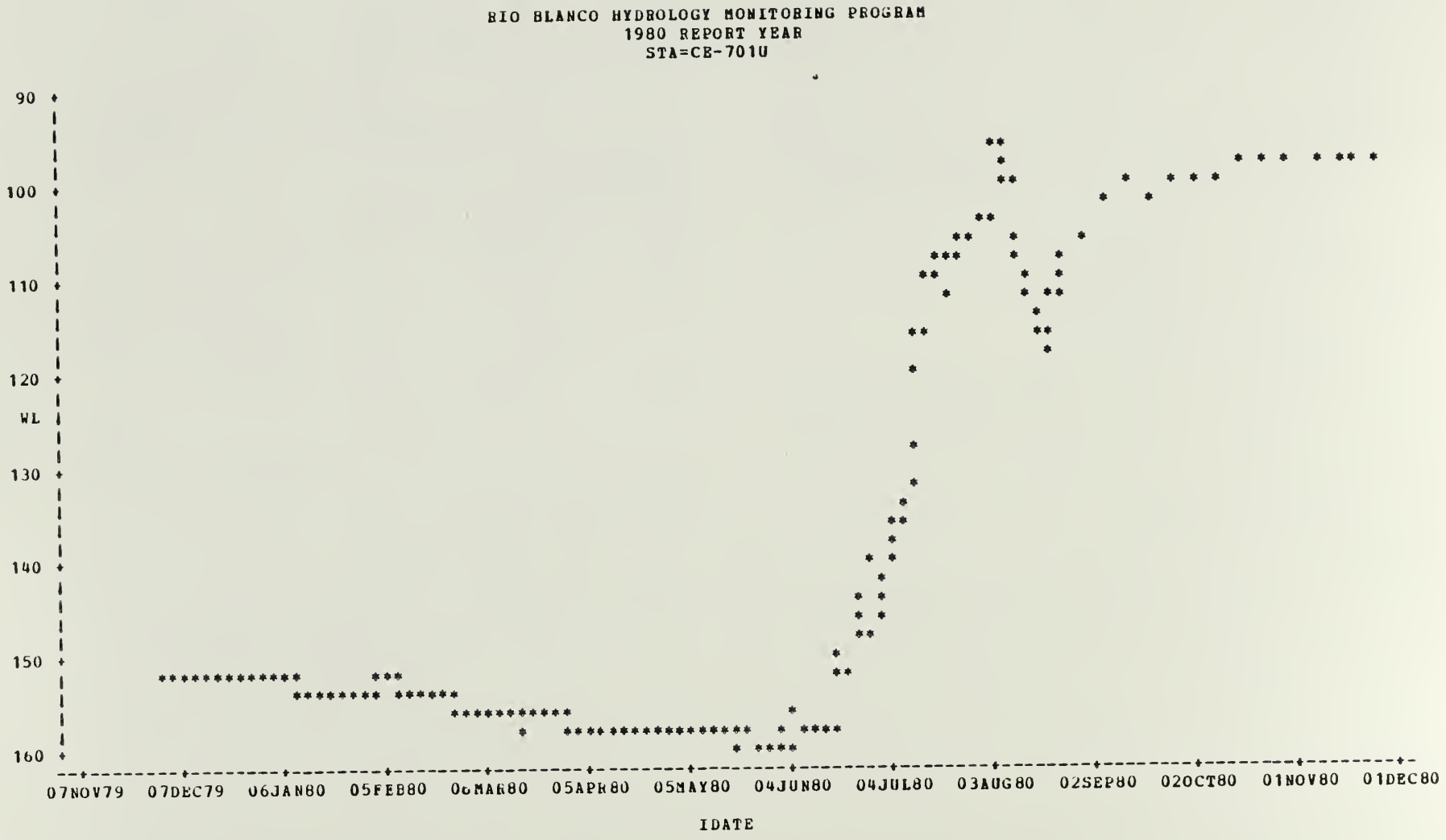


Figure 5-13. 1980 Report Year Water Level (WL depth to water in feet) Data, Well CE-701U, Tract C-a

Figure 5-14. 1980 Report Year Water Level (WL depth to water in feet) Data, Well CE-702U, Tract C-a

Figure 5-15. 1980 Report Year Water Level (WL depth to water in feet) Data, Well CE-709U, Tract C-a

then increased through the end of 1980 to levels similar to minimum levels observed during 1979.

Wells GS-9U and GS-M2U are not expected to respond to mine dewatering operations because of location. GS-9U is located in the graben and GS-M2U is far from the mining activities. The hydrograph of GS-9U shows a seasonal cycle that is probably due to recharge effects (Figure 5-16). A similar cycle, though with less abrupt water level changes, was observed during 1979. Water levels at GS-M2U were relatively steady during 1979 at 217 to 218 feet. Similar data were noted during the 1980 report year (Figure 5-17).

Physical data for the lower aquifer monitoring wells are compared to 1975 and 1976 report year observations in Table 5-24. Levels of pH and conductivity were generally somewhat greater during 1980 than during the baseline periods. The conductivity decrease indicated for CE-702L may be due to inaccurate baseline data. Minimum water temperatures decreased at several locations relative to the baseline (e.g., CE-702L, GS-M4L, GS-15L, and TO-2L). Water levels at most lower aquifer wells were somewhat lower than baseline levels. Physical data for the lower aquifer are presented in Appendix 5-2.4.

Water levels in most lower aquifer wells are commonly stable as this aquifer is not appreciably affected by present development. Well CE-702L had shown increasing water levels at the end of the 1979 report year. This trend continued through April 1980 (Figure 5-18) but at a slower rate during 1980. This is a response to reinjection at TO-3U from natural fracture connection between upper and lower aquifer in the northeast corner of the tract. Well GS-15L exhibits long cycles in water level. The 1979 cycle had a maximum water level of about 72 feet below the surface in January through March 1979 and a minimum of about 75 feet in August and September 1979. Similarly, the 1980 report year data showed a rise from November 1979 through August 1980 followed by a decline (Figure 5-19). These cycles represent natural fluctuations in water level.

b. Water Quality Data - Deep aquifer water quality data for the 1980 report year are tabulated in Appendix 5-2.5. Deep aquifer wells for which data were collected are as follows:

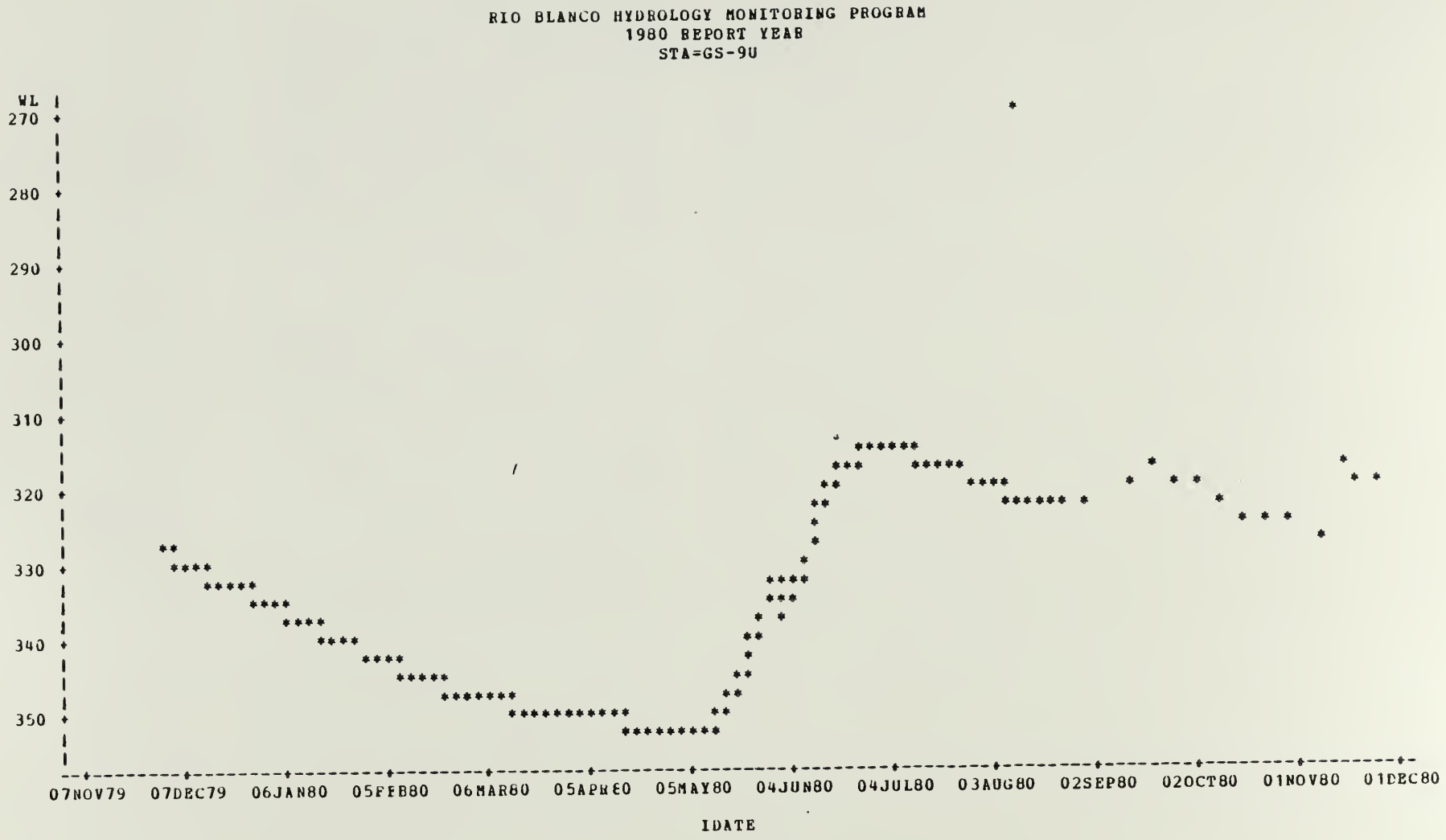


Figure 5-16. 1980 Report Year Water Level (WL depth to water in feet) Data, Well GS-9U, Tract C-a

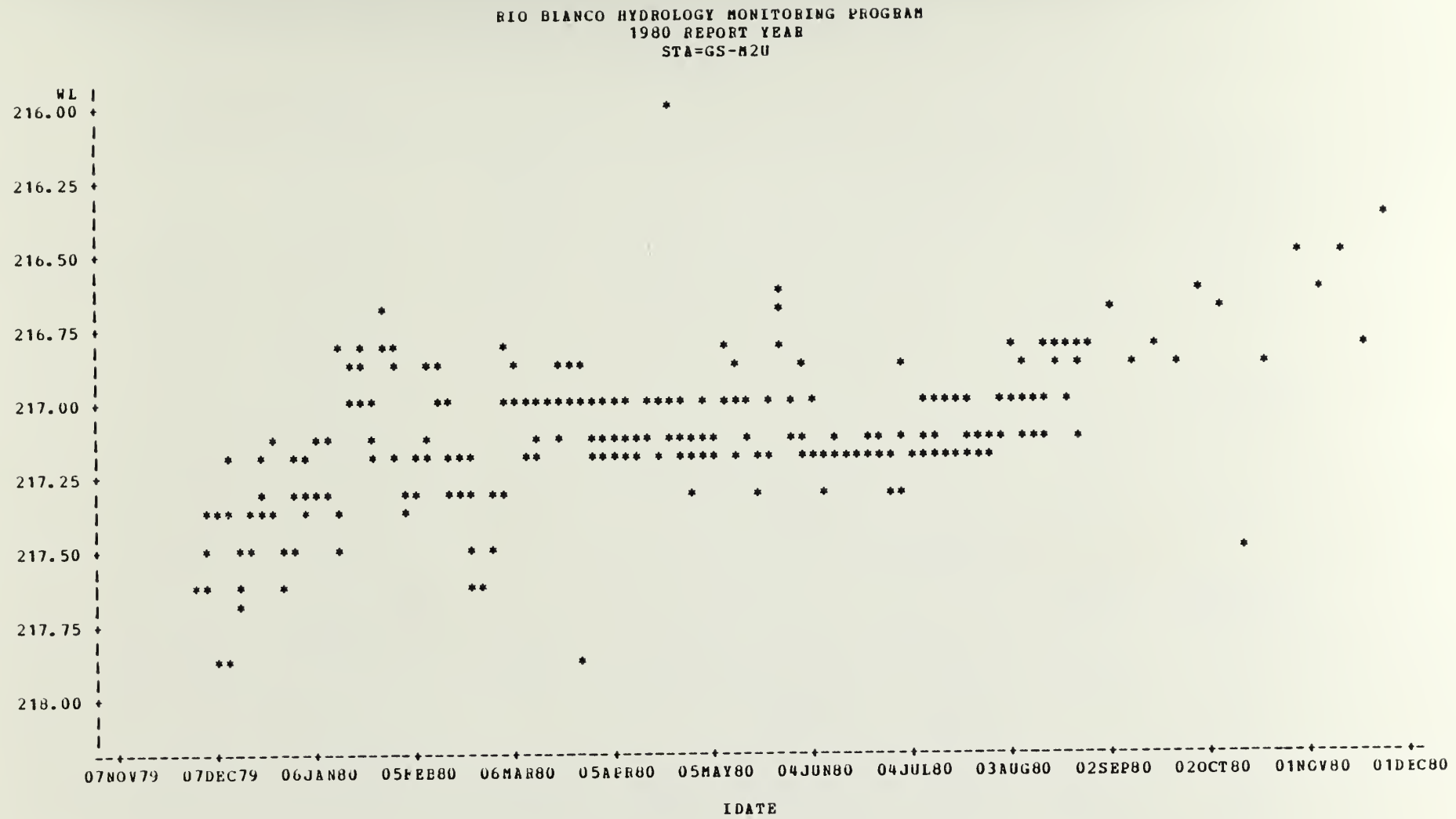


Figure 5-17. 1980 Report Year Water Level (WL depth to water in feet) Data, Well GS-M2U, Tract C-a

Table 5-24. Comparison of Physical Monitoring Data, Lower Aquifer, Tract C-a (report year 1980 is compared to baseline report years 1975 and 1976)

Well	Parameter[2]	1980 Mean		1980 Minimum		1980 Maximum[1]	
		≥1975	≥1976	≤1975	≤1976	≥1975	≥1976
CE-702L	Water Level	..	..	..	36.3/42	..	..
	Temperature	..	..	11.2/15.3	11.2/18.8	..	..
	pH	..	..	..	7.2/7.4	..	8.6/7.6
	Conductivity	..	..	1475/4000	1475/4250	..	..
CE-709L[3]	Water Level	192/144	192/161	..	..	254/177	254/165
	Temperature	..	..	..	..	..	..
	pH	..	..	..	..	..	8.5/8.0
	Conductivity	..	..	..	..	1800/1560	1800/1140
GS-M4L	Water Level	..	..	..	546/564	..	..
	Temperature	..	..	13.1/13.9	13.1/14.8	..	..
	pH	8.1/7.0	..	..	..	8.9/7.6	8.9/7.2
	Conductivity	..	..	1375/1700	1375/1920	..	..
GS-15L[3]	Water Level	372/351	372/372	..	..	374/366	..
	Temperature	..	..	..	12.8/13.9	..	..
	pH	..	..	..	..	9/7.6	9/7.8
	Conductivity	..	..	..	..	..	3200/2400
GS-17L	Water Level	..	..	..	..	..	..
GS-19L	Water Level	..	..	..	..	..	..
GS-4-5L	Water Level	106/81	106/104	..	..	109/100	109/100
TO-1L	Water Level	135/123	135/134	..	..	..	139/138
TO-2L	Water Level	547/354	547/363	..	..	549/379	549/377
	Temperature	..	..	..	13.1/14.6	..	..
	pH	7.9/7.0	..	..	..	8.8/7.4	8.8/7.6
	Conductivity	1875/1226	..	..	..	2100/1910	2100/1070

[1] 1976 data other than water level have one or two observations; thus, only minimum and maximum values compared

[2] Units: water level - depth to water, rounded to nearest foot; temperature - °C; pH - pH units; conductivity - µmhos/cm at 25°C

[3] 1980 data other than water level have two observations, only minimum and maximum values compared

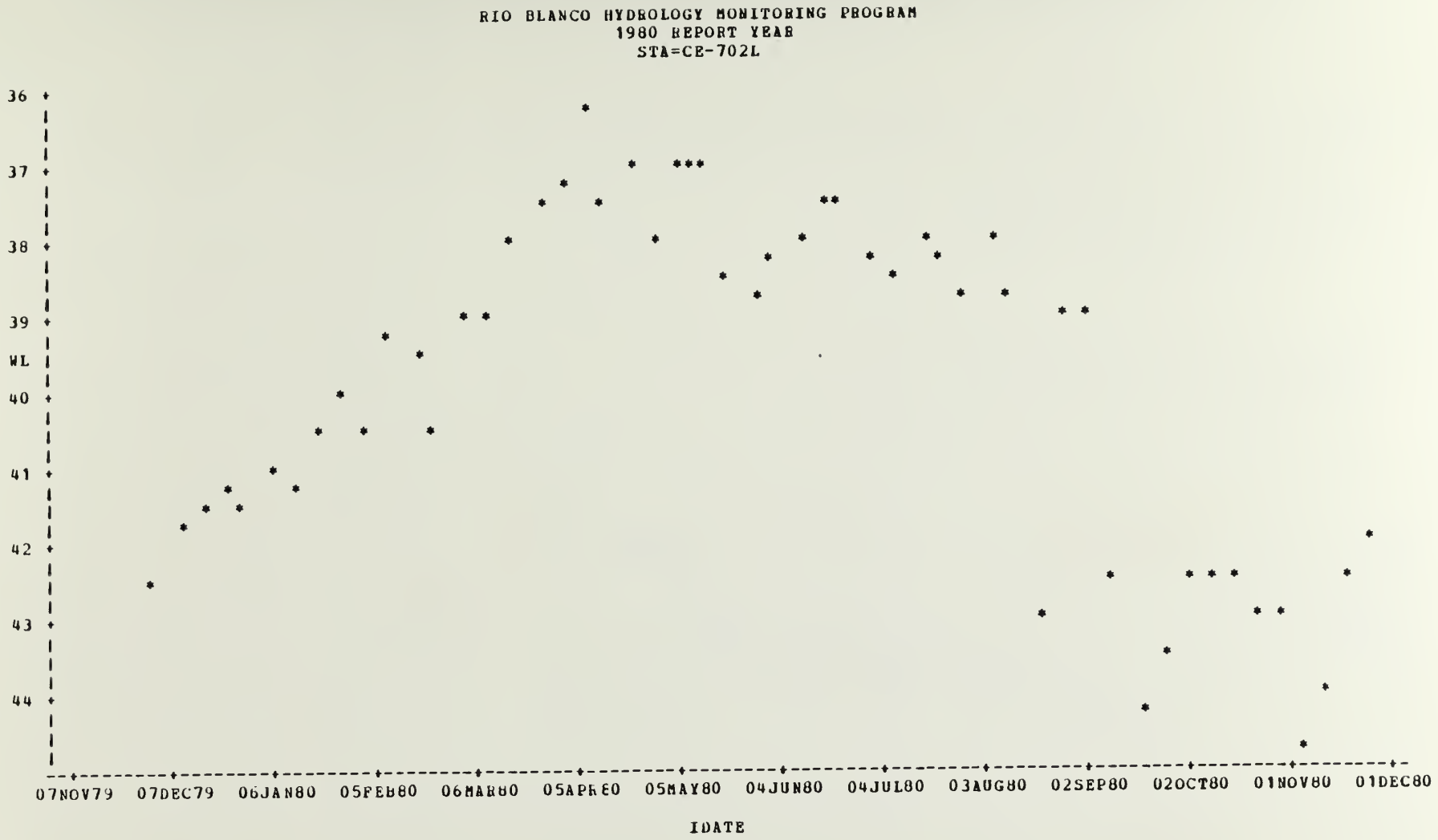


Figure 5-18. 1980 Report Year Water Level (WL depth to water in feet) Data, Well CE-702L, Tract C-a

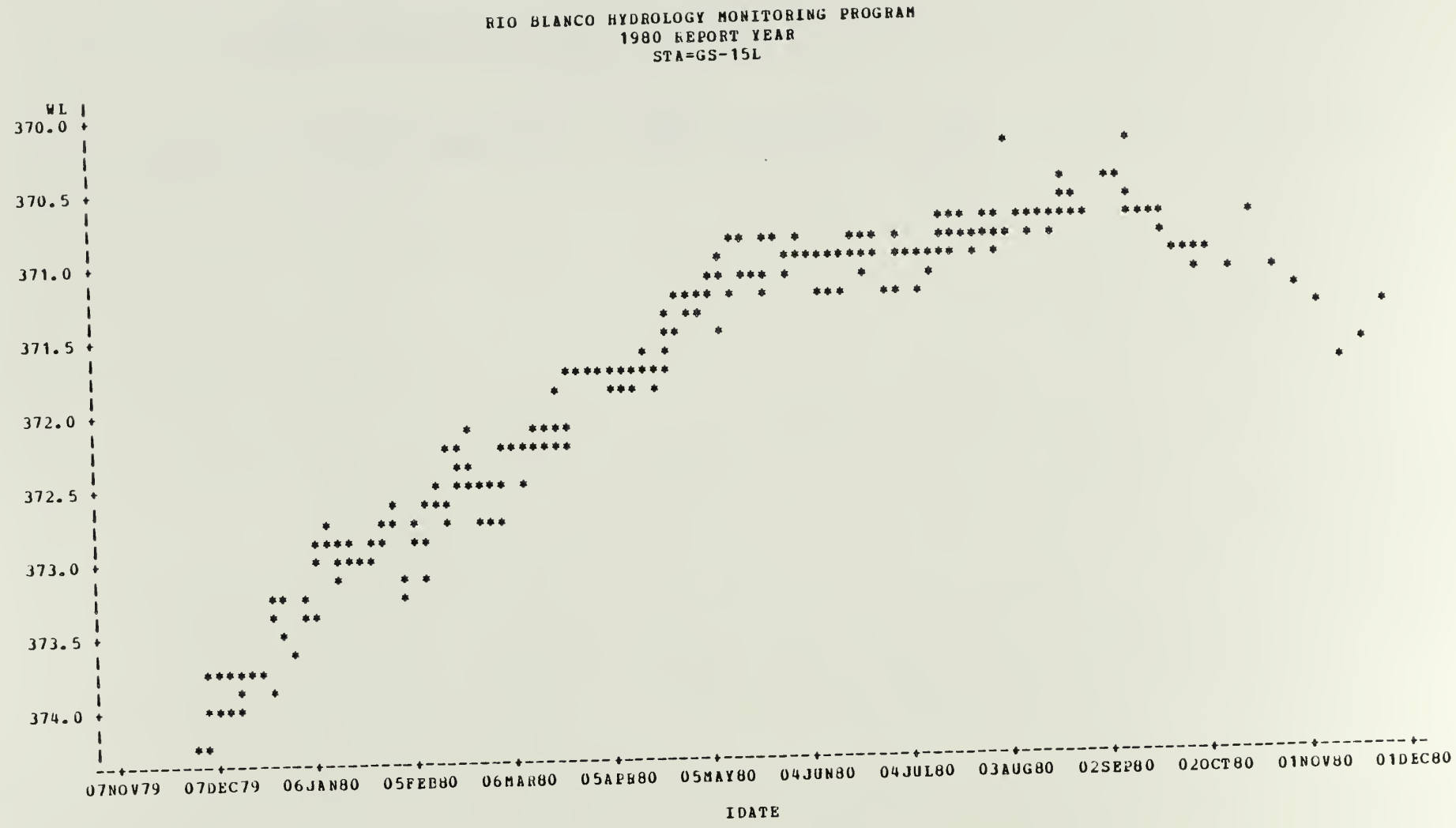


Figure 5-19. 1980 Report Year Water Level (WL depth to water in feet) Data, Well GS-15L, Tract C-a

Upper Aquifer		Lower Aquifer
AM-2U	GS-M6U	CE-702L
AM-3AU	GS-M8U	CE-709L
CE-701U	GS-M10U	GS-15L
CE-702U	GS-M11U	GS-17L
CE-705AU	GS-M12U	GS-18L
CE-707U	GS-9U	
CE-709U	GS-10U	
GS-M1U	GS-12U	
GS-M2U	GS-13U	
GS-M3U	GS-15U	
GS-M4U	GS-19U	

These water quality data were evaluated in two ways. Means and maxima for the 1980 report year were compared to means and maximum values for the baseline report years 1975 and 1976. In addition, MANOVA was performed on data for selected chemical constituents to evaluate differences between report years.

The results of comparisons of means and maximum observations for the upper aquifer are shown in Tables 5-25 through 5-37. Upper aquifer Wells AM-2U, GS-12U, and GS-13U were sampled once or twice in 1980. These data are compared to baseline maximum observations in Table 5-38. Wells GS-M6U, GS-M8U, GS-M10U, GS-M11U, GS-M12U, and GS-19U were not sampled during the baseline and are thus not included in this discussion.

Upper aquifer water quality, when compared for individual wells (Tables 5-25 through 5-37), appears to have increased in pH and the associated constituents akalinity and bicarbonate concentration since the baseline period. The aquifer is somewhat more alkaline than was observed during the baseline.

Concentrations of calcium, magnesium, and sulfate have also increased since the baseline at several upper aquifer locations (e.g., AM-3U, CE-701U, CE-702U, CE-707U, CE-709U, GS-M1U, and GS-15U (note, however, that all three of

Table 5-25. General Comparison of Water Quality, Upper Aquifer Well AM-3U, Tract C-a, Report Year 1980, With Observations for Baseline (1975 and 1976) (data listed show 1980 means or maximum values which exceeded 1975 or 1976 data)

	AM-3U		
	1980 Mean[6]	1980 Maximum[6]	
Constituent[1]	≥1975	≥1975	≥1976[2]
Specific Conductance	1094/976	1100/1020	1100/1010
pH	8.3/7.0	8.5/7.3	8.5/6.9
Alkalinity	377/220	444/315	444/305
HCO_3	438/243	497/370	497/315
Ca	40.9/13.6	53/24	53/31
Mg	48.5/38.8	60/47	60/38
Na	..	..	..
K[3]	..	..	2.0/1.7
Cl	..	..	..
SO_4	277/275	383/305	383/260
F	1.02/0.84	..	1.07/0.9
As	..	..	..
B	..	..	..
Mo[4]	..	..	..
V[4]	..	..	..
Se[5]	..	..	..
Hg[5]	..	..	..
DOC	..	..	11/11
TDS	785/718	..	812/720

[1] Units: specific conductance - µmhos/cm at 25°C; pH - pH units; others - mg/l

[2] Only two 1976 observations, only maxima compared

[3] No 1975 data

[4] One 1980 observation

[5] Two 1980 observations, Se < 0.01, Hg < 0.001

[6] Where 1980 mean or maximum value equals or exceeds 1975 or 1976 value the data are listed as 1980 value/1975 value or 1980 value/1976 value. Unless otherwise indicated, the .. indicates that the 1980 value was less than the baseline year value.

Table 5-26. General Comparison of Water Quality, Upper Aquifer Well CE-701U, Tract C-a, Report Year 1980, With Observations for Baseline (1975 and 1976) (data listed show 1980 means or maximum values which exceeded 1975 or 1976 data)

CE-701U	
	1980 Maximum[5]
Constituent[1]	≥1975[2],[3]
Specific Conductance	1500/1120
pH	8.5/6.0
Alkalinity	478/190
HCO_3	550/190
Ca	84/62
Mg	88/27
Na	205/190
K	..
Cl	..
SO_4	425/410
F	0.58/0.40
As	..
B	0.51/0.20
Mo[4]	..
V[4]	..
Se	..
Hg	..
DOC	..
TDS	1056/820

[1] Units: specific conductance - µmhos/cm at 25°C; pH - pH units; others - mg/l

[2] Only two 1975 observations, only maxima compared

[3] No 1976 data

[4] Two 1980 observations

[5] Where 1980 mean or maximum value equals or exceeds 1975 or 1976 value the data are listed as 1980 value/1975 value or 1980 value/1976 value. Unless otherwise indicated, the .. indicates that the 1980 value was less than the baseline year value.

Table 5-27. General Comparison of Water Quality, Upper Aquifer Well CE-702U, Tract C-a, Report Year 1980, With Observations for Baseline (1975 and 1976) (data listed show 1980 means or maximum values which exceeded 1975 or 1976 data)

	CE-702U		
	1980 Mean[6]	1980 Maximum[6]	
Constituent[1]	≥1975	≥1975	≥1976[2]
Specific Conductance	..	..	..
pH	8.1/7.6	8.3/8	8.3/7.6
Alkalinity	..	..	..
HCO_3	..	..	..
Ca	31.7/7.9	42.7/15	42.7/8.8
Mg	65.4/7.1	88/9.7	88/11
Na	..	..	..
K[3]	..	..	..
Cl	..	..	..
SO_4	331/46.3	378/100	378/15
F	..	..	..
As[4]	..	..	..
B	..	..	..
Mo[5]	..	..	..
V[5]	..	..	..
Se[4]	..	..	..
Hg[4]	..	..	..
DOC	..	..	..
TDS	..	..	..

[1] Units: specific conductance - µmhos/cm at 25°C; pH - pH units; others - mg/l

[2] Two 1976 observations, only maxima compared

[3] No 1975 data

[4] Two 1980 observations

[5] One 1980 observation

[6] Where 1980 mean or maximum value equals or exceeds 1975 or 1976 value the data are listed as 1980 value/1975 value or 1980 value/1976 value. Unless otherwise indicated, the .. indicates that the 1980 value was less than the baseline year value.

Table 5-28. General Comparison of Water Quality, Upper Aquifer Well CE-705AU, Tract C-a, Report Year 1980, With Observations for Baseline (1975 and 1976) (data listed show 1980 means or maximum values which exceeded 1975 or 1976 data)

	CE-705AU	
	1980 Mean[1/5/]	1980 Maximum[1/5/]
Constituent[2/]	≥1975	≥1975
Specific Conductance	..	..
pH	7.8/6.6	8.5/7.7
Alkalinity	463/432	514/490
HCO_3	541/522	607/600
Ca	..	..
Mg	70.6/68	96/92
Na	..	..
K[3/]	..	..
Cl	10.1/3.2	25.6/8.6
SO_4	..	..
F	..	..
As[4/]	..	..
B	..	..
Mo[3/]	..	..
V[3/]	..	..
Se[4/]	..	..
Hg[4/]	..	..
DOC	..	15/4
TDS	..	

1/ No 1976 data

2/ Units: specific conductance - µmhos/cm at 25°C; pH - pH units; others - mg/l

3/ No 1975 data

4/ Two 1980 observations

5/ Where 1980 mean or maximum value equals or exceeds 1975 or 1976 value the data are listed as 1980 value/1975 value or 1980 value/1976 value. Unless otherwise indicated, the .. indicates that the 1980 value was less than the baseline year value.

Table 5-29. General Comparison of Water Quality, Upper Aquifer Well CE-707U, Tract C-a, Report Year 1980, With Observations for Baseline (1975 and 1976) (data listed show 1980 means or maximum values which exceeded 1975 or 1976 data)

	CE-707U		
	1980 Mean[6]	1980 Maximum[6]	
Constituent[1]	≥1975	≥1975	≥1976[2]
Specific Conductance	..	1650/1560	1650/1530
pH	7.7/6.5	8.2/6.8	8.2/6.6
Alkalinity	..	..	..
HCO_3	..	..	..
Ca	..	..	128/110
Mg	87.4/32.5	106/55	106/96
Na	..	..	..
K[3]	..	..	..
Cl	17.4/12.8	25/21	..
SO_4	395/352	600/385	600/370
F	0.22/0.20	0.33/0.30	..
As[4]	..	..	..
B	..	..	0.42/0.20
Mo[5]	..	..	..
V[5]	..	..	..
Se[4]	..	..	..
Hg[4]	..	..	..
DOC	7.7/6.6	14/9	14/14
TDS	..	..	1052/1030

1/ Units: specific conductance - µmhos/cm at 25°C; pH - pH units; others - mg/l

2/ Two 1976 observations, only maxima compared

3/ No 1975 data

4/ One 1980 observation

5/ No 1980 data

6/ Where 1980 mean or maximum value equals or exceeds 1975 or 1976 value the data are listed as 1980 value/1975 value or 1980 value/1976 value. Unless otherwise indicated, the .. indicates that the 1980 value was less than the baseline year value.

Table 5-30. General Comparison of Water Quality, Upper Aquifer Well CE-709U, Tract C-a, Report Year 1980, With Observations for Baseline (1975 and 1976) (data listed show 1980 means or maximum values which exceeded 1975 or 1976 data)

	CE-709U		
	1980 Mean[6]	1980 Maximum[6]	
Constituent[1]	≥1975	≥1975	≥1976[2]
Specific Conductance	1620/1269	1700/1541	1700/1200
pH	7.4/6.4	8.0/7.0	8.0/7.1
Alkalinity	465/381	531/425	531/360
HCO_3	553/448	609/520	609/440
Ca	121/60	136/76	136/29
Mg	97.3/73	124/86	124/91
Na	..	..	165/115
K[3]	..	..	..
Cl	16.9/10.2	23.4/21	..
SO_4	514/397	610/370	610/285
F	0.48/0.21	0.63/0.30	0.63/0.60
As[4]	..	..	..
B	..	..	..
Mo[5]	..	..	..
V[5]	..	..	..
Se[4]	..	..	..
Hg[4]	..	..	..
DOC	13.3/8.3	29/14	29/9
TDS	1215/895	1248/970	1215/790

[1] Units: specific conductance - µmhos/cm at 25°C; pH - pH units; others - mg/l

[2] Two 1976 observations, only maxima compared

[3] No 1975 data

[4] Two 1980 observations

[5] One 1980 observation

[6] Where 1980 mean or maximum value equals or exceeds 1975 or 1976 value the data are listed as 1980 value/1975 value or 1980 value/1976 value. Unless otherwise indicated, the .. indicates that the 1980 value was less than the baseline year value.

Table 5-31. General Comparison of Water Quality, Upper Aquifer Well GS-M1U, Tract C-a, Report Year 1980, With Observations for Baseline (1975 and 1976) (data listed show 1980 means or maximum values which exceeded 1975 or 1976 data)

	GS-M1U		
	1980 Mean[6]	1980 Maximum[6]	
Constituent[1]	≥1975	≥1975	≥1976[2]
Specific Conductance	1430/1169	1800/1220	1800/1140
pH	7.9/6.7	8.3/7.0	8.3/6.8
Alkalinity	381/318	408/330	408/330
HCO_3	442/378	478/395	478/380
Ca	55.9/39.7	80/66	80/47
Mg	43.5/30.7	57/38	57/33
Na	242/221	300/230	300/250
K[3]	..	..	..
Cl	..	..	..
SO_4	430/316	631/350	631/375
F	..	..	..
As[4]	..	..	..
B	..	0.45/0.30	0.45/0.20
Mo[5]	..	..	..
V[5]	..	..	..
Se[4]	..	..	..
Hg[4]	..	..	..
DOC	..	15/12	15/6.8
TDS	1075/840	1260/910	1260/940

1/ Units: specific conductance - µmhos/cm at 25°C; pH - pH units; others - mg/l

2/ Two 1976 observations, only maxima compared

3/ No 1975 data

4/ Two 1980 observations

5/ One 1980 observation

6/ Where 1980 mean or maximum value equals or exceeds 1975 or 1976 value the data are listed as 1980 value/1975 value or 1980 value/1976 value. Unless otherwise indicated, the .. indicates that the 1980 value was less than the baseline year value.

Table 5-32. General Comparison of Water Quality, Upper Aquifer Well GS-M2U, Tract C-a, Report Year 1980, With Observations for Baseline (1975 and 1976) (data listed show 1980 means or maximum values which exceeded 1975 or 1976 data)

	GS-M2U		
	1980 Mean[6]	1980 Maximum[6]	
Constituent[1]	≥1975	≥1975	≥1976[2]
Specific Conductance	..	..	..
pH	9.3/6.7	9.6/6.9	9.6/7.2
Alkalinity	516/510	749/530	749/505
HCO_3	..	..	..
Ca	..	..	..
Mg	..	..	120/120
Na	212/201	..	..
K[3]	..	..	..
Cl	..	..	..
SO_4	..	..	..
F	..	..	..
As[4]	..	..	..
B	..	..	..
Mo[5]	..	..	..
V[5]	..	..	..
Se[4]	..	..	..
Hg[4]	..	..	..
DOC	12.3/8.6	25/10	25/8
TDS	..	..	..

[1] Units: specific conductance - µmhos/cm at 25°C; pH - pH units; others - mg/l

[2] Two 1976 observations, only maxima compared

[3] No 1975 data

[4] Two 1980 observations

[5] One 1980 observation

[6] Where 1980 mean or maximum value equals or exceeds 1975 or 1976 value the data are listed as 1980 value/1975 value or 1980 value/1976 value. Unless otherwise indicated, the .. indicates that the 1980 value was less than the baseline year value.

Table 5-33. General Comparison of Water Quality, Upper Aquifer Well GS-M3U, Tract C-a, Report Year 1980, With Observations for Baseline (1975 and 1976) (data listed show 1980 means or maximum values which exceeded 1975 or 1976 data)

	GS-M3U		
	1980 Mean[6]	1980 Maximum[6]	
Constituent[1]	≥1975	≥1975	≥1976[2]
Specific Conductance	..	..	..
pH	9.8/6.7	9.9/7.2	9.8/6.5
Alkalinity	666/429	939/515	939/550
HCO_3	..	..	..
Ca	..	..	..
Mg	..	..	..
Na	..	..	..
K[3]	..	..	..
Cl	..	..	..
SO_4	..	..	..
F	..	..	..
As[4]	..	..	..
B	..	..	0.4/0.4
Mo[5]	..	..	..
V[5]	..	..	..
Se[4]	..	..	..
Hg[4]	..	..	..
DOC	..	42/27	42/6
TDS	..	..	..

1/ Units: specific conductance - μmhos/cm at 25°C; pH - pH units; others - mg/l

2/ Two 1976 observations, only maxima compared

3/ No 1975 data

4/ Two 1980 observations

5/ One 1980 observation

6/ Where 1980 mean or maximum value equals or exceeds 1975 or 1976 value the data are listed as 1980 value/1975 value or 1980 value/1976 value. Unless otherwise indicated, the .. indicates that the 1980 value was less than the baseline year value.

Table 5-34. General Comparison of Water Quality, Upper Aquifer Well GS-M4U, Tract C-a, Report Year 1980, With Observations for Baseline (1975 and 1976) (data listed show 1980 means or maximum values which exceeded 1975 or 1976 data)

	GS-M4U		
	1980 Mean[6]	1980 Maximum[6]	
Constituent[1]	≥1975	≥1975	≥1976[2]
Specific Conductance	..	2400/2250	2400/2060
pH	8.1/6.8	9.6/7.1	9.6/6.2
Alkalinity	..	..	631/565
HCO_3	..	..	745/690
Ca	..	..	130/138
Mg	111/103	172/130	172/135
Na	..	..	326/240
K[3]	..	..	..
Cl	..	48/27	48/41
SO_4	..	..	770/750
F	0.15/0.07	..	0.29/0.20
As[4]	..	..	..
B	..	0.83/0.20	0.83/0.40
Mo[5]	..	..	..
V[5]	..	..	..
Se[4]	..	..	..
Hg[4]	..	..	..
DOC[4]	..	39/18	39/12
TDS	..	..	..

1/ Units: specific conductance - µmhos/cm at 25°C; pH - pH units; others - mg/l

2/ Two 1976 observations, only maxima compared

3/ No 1975 data

4/ Two 1980 observations

5/ One 1980 observation

6/ Where 1980 mean or maximum value equals or exceeds 1975 or 1976 value the data are listed as 1980 value/1975 value or 1980 value/1976 value. Unless otherwise indicated, the .. indicates that the 1980 value was less than the baseline year value.

Table 5-35. General Comparison of Water Quality, Upper Aquifer Well GS-10U, Tract C-a, Report Year 1980, With Observations for Baseline (1975 and 1976) (data listed show 1980 means or maximum values which exceeded 1975 or 1976 data)

	GS-10U		
	1980 Mean[5]	1980 Maximum[5]	
Constituent[1]	≥1975	≥1975	≥1976[2]
Specific Conductance	..	..	..
pH	7.4/6.5	8.5/6.8	8.5/6.8
Alkalinity	..	..	..
HCO_3	..	..	..
Ca	..	..	..
Mg	126/116	188/140	..
Na	..	..	..
K[3]	..	..	..
Cl	..	21.9/21	21.9/16
SO_4	..	..	..
F	..	..	0.71/0.30
As[4]	..	..	..
B	..	..	0.66/0.40
Mo[4]	..	..	..
V[4]	..	..	..
Se[4]	..	..	..
Hg[4]	..	5/<0.002	5/<0.001
DOC	18.6/6.4	77/14	77/15
TDS	..	..	..

[1] Units: specific conductance - µmhos/cm at 25°C; pH - pH units; others - mg/l

[2] Two or three 1976 observations, only maxima compared

[3] No 1975 data

[4] Two or three 1980 observations

[5] Where 1980 mean or maximum value equals or exceeds 1975 or 1976 value the data are listed as 1980 value/1975 value or 1980 value/1976 value. Unless otherwise indicated, the .. indicates that the 1980 value was less than the baseline year value.

Table 5-36. General Comparison of Water Quality, Upper Aquifer Well GS-15U, Tract C-a, Report Year 1980, With Observations for Baseline (1975 and 1976) (data listed show 1980 means or maximum values which exceeded 1975 or 1976 data)

	GS-15U		
	1980 Mean[6]	1980 Maximum[6]	
Constituent[1]	≥1975	≥1975	≥1976[2]
Specific Conductance	2265/1374	2560/1490	2560/1475
pH	..	..	8.2/7.3
Alkalinity[3]	..	571/383	571/440
HCO_3[3]	..	678/445	678/520
Ca	113/13.4	128/30	128/43
Mg	160/38.8	221/66	221/83
Na	..	..	290/250
K[4]	..	..	3.0/2.1
Cl	..	..	25.6/8.2
SO_4	937/346	1050/440	1050/415
F	..	5.3/2.4	5.3/1.3
As[5]	..	..	..
B	0.34/0.16	0.71/0.50	..
Mo[5]	..	..	..
V[5]	..	..	..
Se[5]	..	..	..
Hg[5]	..	1/<0.002	1/<0.001
DOC	10.8/5.4	49/9	49/7
TDS	1783/912	1892/1040	1892/1020

[1] Units: specific conductance - μmhos/cm at 25°C; pH - pH units; others - mg/l

[2] Two 1976 observations, only maxima compared

[3] Two 1975 observations

[4] No 1975 data

[5] Two or three 1980 observations

[6] Where 1980 mean or maximum value equals or exceeds 1975 or 1976 value the data are listed as 1980 value/1975 value or 1980 value/1976 value. Unless otherwise indicated, the .. indicates that the 1980 value was less than the baseline year value.

Table 5-37. General Comparison of Water Quality, Upper Aquifer Well GS-9U, Tract C-a, Report Year 1980, With Observations for Baseline (1975 and 1976) (data listed show 1980 means or maximum values which exceeded 1975 or 1976 data)

	GS-9U		
	1980 Mean[6]	1980 Maximum[6]	
Constituent[1]	≥1975	≥1975	≥1976[2]
Specific Conductance	..	..	..
pH	7.5/6.6	8.1/7.0	8.1/6.9
Alkalinity	..	..	..
HCO_3	..	..	..
Ca	..	..	..
Mg	66.9/51	72/71	..
Na	..	..	..
K[3]	..	..	..
Cl	..	..	13.7/8.3
SO_4	..	..	..
F	..	..	0.36/0.30
As[4]	..	..	..
B	0.21/0.11	..	0.42/0.30
Mo[4]	..	..	..
V[4]	..	..	..
Se[4]	..	..	..
Hg[4]	..	..	..
DOC[5]	..	..	..
TDS	..	..	..

[1] Units: specific conductance - µmhos/cm at 25°C; pH - pH units; others - mg/l

[2] Two 1976 observations, only maxima compared

[3] No 1975 data

[4] No 1980 data

[5] Two 1980 observations

[6] Where 1980 mean or maximum value equals or exceeds 1975 or 1976 value the data are listed as 1980 value/1975 value or 1980 value/1976 value. Unless otherwise indicated, the .. indicates that the 1980 value was less than the baseline year value.

Table 5-38. Comparison of 1980 Report Year Upper Aquifer Water Quality Data With Baseline (1975 and 1976) Report Year Maximum Observations

Constituent[1/]	AM-2AU			GS-12U			GS-13U		
	1980	1975	1976	1980	1975	1976	1980	1975	1976
Specific Conductance	1450	1550	1500	1840	1830	1430	1840	1710	1480
pH	7.8	7.1	7.0	7.6	6.8	7.6	7.3	7.0	7.0
Alkalinity	544	530	590	631	550	395	581	510	490
HCO_3	665	645	720	738	640	480	686	620	690
Ca	40	83	52	71	110	31	115	105	38
Mg	83	66	70	80	85	77	103	82	115
Na	240	285	330	229	260	300	204	250	235
K	2.0	..	4.5	1.1	..	5.0	0.55	..	2.0
Cl	21	14	55	8.4	27	55	11.3	14	9.6
SO_4	384	410	360	433	520	540	551	480	420
F	0.2	2.5	0.3	<0.1	0.3	0.1	0.1	0.5	0.9
As	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
B	0.2	2.2	0.5	0.36	4.8	1.4	0.32	1.0	1.6
Mo	..	..	0.2	<0.1	..	<0.1	<0.1	..	..
V	..	..	..	<0.5	..	..	<0.5	..	..
Se	<0.01	..	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Hg	<0.001	<0.01	<0.001	1	<0.002	<0.001	<0.3	<0.002	<0.001
DOC	5	14	13	71	50	14	74	12	6.2
TDS	1050	1160	1140	1308	1290	1040	1396	1240	1320

[1/] Units: specific conductance - μmhos/cm at 25°C; pH - pH units; others - mg/l

these ions have not increased at each of these wells)). These increases in major inorganic ion concentrations have resulted in mean concentration increases in TDS and specific conductance at several wells.

Trace constituents data evaluated here (fluoride, arsenic, boron, molybdenum, vanadium, selenium, and mercury) indicated that levels observed during the 1980 report year were generally comparable to baseline observations. Some observations of increases in fluoride and boron were noted (e.g., Wells AM-3U, CE-701U, CE-707U, CE-709U, GS-M4U, GS-10U, and GS-15U), but no consistent trends were apparent and the indicated changes were usually small.

Dissolved organic carbon levels were somewhat elevated relative to the baseline at several upper aquifer wells. Some of the 1980 maximum observations (Wells CE-701U, CE-705AU, CE-709U, GS-M2U, GS-M3U, GS-M4U, GS-M10U, GS-15U, GS-12U, and GS-13U) are being reevaluated for potential analytical problems. These data (>20 mg/l) are not comparable to more recent data and do not reflect a definite trend in upper aquifer water quality.

To further evaluate report year differences, MANOVA was performed testing the report year main effect (Table 5-39) for upper aquifer water quality. For every constituent included in the analysis, there were significant differences between the report years (1975 through 1980). Also, the 1980 report year was significantly different from 1975 and/or 1976 (the baseline report years) for several constituents. However, with the exception of the constituents pH, calcium, magnesium, and sulfate, the overall means for 1980 were lower than those for 1975 and/or 1976. Report year means for these constituents in the upper aquifer are as follows:

	1975	1976	1978	1979	1980
pH	6.9	6.4	7.6	6.8	7.6
Calcium	63.3	47.7	29.0	63.6	74.9
Magnesium	55.2	68.3	75.1	78.9	80.2
Sulfate	343	350	390	428	428

Table 5-39. Summary of MANOVA of Differences in Water Quality Over Report Years Since Baseline Study Initiation, Upper Aquifer Stations, Tract C-a (Duncan's test results show years significantly different from 1980 report year)

Variable	MANOVA Results		Duncan's Test
	Pr > F[1/]	Significant[2/]	Report Years Significantly Different From 1980
Temperature	0.0001	*	1975, 1976, 1978, 1979
Specific Conductance	0.0001	*	None
pH	0.0001	*	1975, 1976, 1979
HCO_3	0.0001	*	1975, 1979
CO_3	0.0001	*	None
Ca	0.0079	*	1976, 1978
Mg	0.0001	*	1975
Na	0.0001	*	1975, 1976
K	0.0001	*	1975, 1976, 1978, 1979
Cl	0.0039	*	1975, 1976
SO_4	0.0048	*	1975
F	0.0001	*	1975
As	0.0001	*	1975, 1976, 1978
B	0.0001	*	1975, 1976
Mo	0.0001	*	1976
Se	0.0001	*	1975, 1976, 1978
Hg	0.0098	*	1975, 1976, 1978, 1979
DOC	0.0001	*	1979
TDS	0.0001	*	1975, 1976, 1979

1/ Pr > F: probability of greater F value; if Pr > F is small (e.g. <0.05), it indicates significance

2/ At 5% level

The general conclusion from this evaluation is that pH, calcium, magnesium, and sulfate concentrations in the upper aquifer have changed significantly since the baseline. Several factors (including natural variability, sampling errors, local changes in aquifer chemical equilibria due to the presence of wells, and perhaps more general equilibria changes due to dewatering) interact to create the observed changes in aquifer water quality data. The changes are considered to be geochemical in nature and not the result of retorting or other development impacts.

Mean and maximum water quality observation analyses for selected lower aquifer stations are presented in Table 5-40 and 5-41. Examination of these data indicates that maximum observations of pH, alkalinity, and bicarbonate concentrations, as well as concentrations of several other major inorganic ions, TDS, and specific conductance, have increased relative to the baseline at several lower aquifer locations. Some of these results, indicating large changes, may be due to spurious observations. An overall analysis of lower aquifer water quality is provided by the MANOVA results (Table 5-42). These results show several constituents with significant differences between report years. In addition, many differences between the 1980 report year and the baseline report years (1975 and 1976) were identified. However, with the exception of pH, the overall means for 1980 data were lower than 1975 and/or 1976 overall mean values for the significantly different constituents. Report year means for pH in the lower aquifer are as follows:

	1975	1976	1980
pH	7.2	6.9	8.4

Table 5-40. General Comparison of Water Quality, Lower Aquifer Well GS-15L, Tract C-a, Report Year 1980, With Observations for Baseline (1975 and 1976) (data listed show 1980 means or maximum values which exceeded 1975 or 1976 data)

	GS-15L		
	1980 Mean[1/5/]	1980 Maximum[5/]	
Constituent[2/]	≥1975	≥1975	≥1976[1/]
Specific Conductance	3063/2447	..	4200/2400
pH	..	9.5/7.6	9.5/7.8
Alkalinity	1555/734	2470/2050	2470/1180
HCO_3	1718/383	..	..
Ca	..	..	15/8.2
Mg	770/424	..	..
Na	..	..	1200/650
K[3/]	..	..	5.0/4.0
Cl	58.1/32.9	112/48	112/37
SO_4	..	..	524/410
F	26.8/18.8	..	55.2/28
As[4/]	..	<0.01/<0.01	<0.01/<0.01
B	..	..	2.2/1.0
Se[4/]	..	<0.01/<0.01	<0.01/<0.01
Hg[4/]	..	<0.001/<0.002	<0.001/<0.001
DOC	21.7/18.6	39/73	39/13
TDS	2244/1677	3020/2950	3020/1750

1/ Two 1976 observations, only maxima compared

2/ Units: specific conductance - µmhos/cm at 25°C; pH - pH units; others - mg/l

3/ No 1975 data

4/ One 1980 observation, only maxima compared

5/ Where 1980 mean or maximum value equals or exceeds 1975 or 1976 value the data are listed as 1980 value/1975 value or 1980 value/1976 value. Unless otherwise indicated, the .. indicates that the 1980 value was less than the baseline year value.

Table 5-41. Comparison of Maximum Concentrations for Selected Lower Aquifer Wells

Constituent[4]	CE-709L[1] 1980 Maximum[7] ≥1975	CE-709L[1] 1980 Maximum[7] ≥1976	GS-17L[1,2] 1980 Maximum[7] ≥1975	GS-18L[2,3] 1980 Maximum[7] ≥1975
Specific Conductance	2000/1557	2000/1140	2400/2000	..
pH	..	8.4/8.0	8.5/8.0	..
Alkalinity	2030/574	2030/600	1312/760	..
HCO_3	2190/840	2190/695	1486/990	..
Ca	..	23/6.6	..	..
Mg	..	26.6/22	..	..
Na	950/430	950/330	632/390	..
K	[5]	4/37	3.7/<1	..
Cl	32/18	..	60.4/42	..
SO_4	..	149/60	..	85.6/50
F	..	12/8	..	..
As	<0.01/<0.01	<0.01/<0.01	<0.01/<0.01	[6]
B	..	1.6/0.5	3.4/0.8	..
Se	<0.01/<0.01	<0.01/<0.01	<0.01/<0.01	[6]
Hg	<0.001/<0.002	<0.001/<0.001	..	[6]
DOC	28/14	..	[5]	[6]
TDS	3640/1170	3640/750	1660/1330	..

[1] Two 1980 observations, only maxima compared

[2] No 1976 data

[3] One 1980 observation, only maxima compared

[4] Units: specific conductance - µmhos/cm at 25°C; pH - pH units; others - mg/l

[5] No 1975 data

[6] No 1980 data

[7] Where 1980 mean or maximum value equals or exceeds 1975 or 1976 value the data are listed as 1980 value/1975 value or 1980 value/1976 value. Unless otherwise indicated, the .. indicates that the 1980 value was less than the baseline year value.

Table 5-42. Summary of MANOVA of Differences in Water Quality Over Report Years Since Baseline Study Initiation, Lower Aquifer Stations, Tract C-a (Duncan's test results show years significantly different from 1980 report year)

Variable	MANOVA Results		Duncan's Test
	Pr > F[1/]	Significant[2/]	Report Years Significantly Different From 1980
Temperature	0.0001	*	1975, 1976
Specific Conductance	0.5748		
pH	0.0001	*	1975, 1976, 1979
HCO_3	0.5536		
CO_3	0.4952		
SO_4	0.0014	*	None
Cl	0.6988		
Ca	0.0001	*	1975
Mg	0.0349	*	None
Na	0.7621		
K	0.0001	*	1975, 1976
F	0.5471		
As	0.0001	*	1975, 1976
B	0.2033		
Mo	0.0001	*	1976
V	0.0343	*	1976
Se	0.0001	*	1975, 1976
Hg	0.0001	*	1975
DOC	0.0003	*	1979
TDS	0.0338	*	1979

[1/] Pr > F: probability of greater F value; if Pr > F is small (e.g. <0.05), it indicates significance

[2/] At 5% level

5.3 DEVELOPMENT ACTIVITIES MONITORING

1. Objectives

The development activities monitoring program examines the direct impacts of specific activities or facilities of the oil shale development on Tract C-a. Monitoring stations for a given activity have been established, as needed, with initiation of the development action.

2. Methods

The development activities which are being monitored include (1) the dewatering of the upper aquifer (and the associated reinjection and surface discharge), and (2) runoff and liquid waste impoundments associated with the MDP development site. The current monitoring stations and activities are summarized in Table 5-43.

3. Results and Discussion

Physical data collected during the 1980 report year development activities monitoring program are presented in Appendix 5-3.1. Data for ponds, surface flow monitoring sites, and dewatering/reinjection monitoring stations are summarized in Tables 5-44 through 4-46, respectively.

Data collected at the East and West Retention Ponds (YERPOND and YWRPOND) were generally comparable to 1979 report year data (Table 5-44). The one exception is an anomalous conductivity reading (7675 µmhos/cm) in the East Pond. The next lower conductivity measurement was 2900 µmhos/cm.

Data for the sour water ponds (YSWPOND-1 through YSWPOND-7) were collected only for the 1980 report year. Thus, no comparisons with past data can be made. Except for occasional high conductivity readings (>5000 µmhos/cm) in some ponds, the water in the various ponds is fairly similar with regard to these general water quality measures (Table 5-44).

Table 5-43. Development Activities Monitoring Program, Tract C-a, 1980 Report Year

Station	Station Description	Sampling Schedule			
		Daily	Weekly	Quarterly	Semi-annually
GS-D1 through GS-D9	Dewatering wells (not all are operational at this time)	WL,[1] Flow	FWQ[2]	WQ-A[3]	WQ-B[4]
YJEFPOND	Settling Pond east of shaft		FWQ		
YERPOND, YWRPOND	East and West Retention Ponds, MDP area	WL			
YCOINJ	Composite reinjection water	WL, FWQ			
YMET3	At USGS Station D	Flow, FWQ			
YBOXFL	Box Elder Gulch, upstream from Station D	Flow			
YSEOFL	Corral Gulch near 84-Ranch	Flow, FWQ			
Y24RDS, Y24RDN	Culvert at 24-Road Crossing, Yellow Creek	Flow, FWQ			
YCULDIS	Discharge point (NPDES) near Visitor's Center	NPDES[5]	F, B[6]		
YLDGEDGE	Leading edge of Yellow Creek flow during discharge				
SPG-MILL	Spring off Corral Gulch at YMET3	Flow, FWQ			

Table 5-43. (Continued)

Station	Station Description	Sampling Schedule			
		Daily	Weekly	Quarterly	Semi-annually
YFLDIS	Discharge point (NPDES), flume below water treatment plant	NPDES	F, B		
YEROPOND, YWROPOND	Runoff collection pond, MDP area			WQ-A	WQ-B
YSWPOND-1 through -7	Sour water ponds, MDP area	WL		WQ-A	WQ-B
YPZPOND1 through 4	Leakage detection piezometers below retention ponds	WL	FWQ		

1/ WL: water level

2/ FWQ: field water quality - pH, conductivity, temperature (also TSS for composite reinjection)

3/ WQ-A: water chemistry constituents listed in Table 5-13

4/ WQ-B: water chemistry constituents listed in Table 5-13

5/ NPDES: pH, conductivity, temperature, TSS, oil, and grease

6/ F, B: fluoride, boron

Table 5-44. Physical Data Summaries for Pond Monitor Sites, Tract C-a

Station	Parameter[1/]	1980 n	1980 $\bar{x}$	1980 Minimum	1980 Maximum	1979 n	1979 $\bar{x}$	1979 Minimum	1979 Maximum
YEROPOND	pH	41	9.1	7.7	11.4	..	..	..	..
	Temperature	41	18.6	2.5	27	..	..	..	..
	Conductivity	41	1709	600	4900	..	..	..	..
YERPOND	pH	331	8.9	6.7	10.7	138	9.5	7.7	10.8
	Temperature	313	13.6	0.1	28	140	14.4	2.6	26.5
	Conductivity	332	1444	285	7675	140	1703	940	3340
YWROPOND	pH	117	8.5	8	9.3	..	..	..	..
	Temperature	115	18.9	1	34	..	..	..	..
	Conductivity	117	2096	1250	5000	..	..	..	..
YWRPOND	pH	330	8.1	7.6	8.8	147	8.4	6.5	9.0
	Temperature	331	15.0	7.9	25	151	14.6	7.4	20.1
	Conductivity	330	1397	1210	1700	151	1259	1020	1560
	TDS	73	1012	961	1051	..	..	..	..
YSWPOND-1	pH	50	8.6	7.8	9.3	..	..	..	..
	Temperature	50	19.0	4.5	24	..	..	..	..
	Level	122	1.69	..	3.12	..	..	..	..
	Conductivity	50	1764	1200	5000	..	..	..	..
YSWPOND-2	pH	51	8.5	7.3	8.9	..	..	..	..
	Temperature	51	19.7	4.5	27	..	..	..	..
	Level	123	1.52	..	2.87	..	..	..	..

Table 5-44. (Continued)

Station	Parameter[1/]	1980 n	1980 $\bar{x}$	1980 Minimum	1980 Maximum	1979 n	1979 $\bar{x}$	1979 Minimum	1979 Maximum
YSWPOND-3	pH	40	8.6	8.3	8.9	..	..	..	..
	Temperature	40	18.9	3	24	..	..	..	..
	Level	113	1.95	..	3.09	..	..	..	..
	Conductivity	40	1786	1300	6400	..	..	..	..
YSWPOND-4	pH	31	8.4	8.1	8.6	..	..	..	..
	Temperature	31	17.5	4.3	23	..	..	..	..
	Level	103	1.97	..	2.78	..	..	..	..
	Conductivity	31	1410	1275	1650	..	..	..	..
YSWPOND-5	pH	4	8.1	8	8.4	..	..	..	..
	Temperature	4	5.7	4	8.8	..	..	..	..
	Level	62	0.29	..	3.21	..	..	..	..
	Conductivity	4	1350	1200	1450	..	..	..	..
YSWPOND-6	pH	4	8.3	8	8.9	..	..	..	..
	Temperature	4	6.7	5	10.2	..	..	..	..
	Level	62	0.45	..	2.7	..	..	..	..
	Conductivity	4	1412	1325	1500	..	..	..	..
YSWPOND-7	pH	4	8.1	7.9	8.2	..	..	..	..
	Temperature	4	6.0	2.5	12.5	..	..	..	..
	Level	62	0.54	..	2.68	..	..	..	..
	Conductivity	4	1388	1250	1500	..	..	..	..

Table 5-44. (Continued)

Station	Parameter[1]	1980 n	1980 $\bar{x}$	1980 Minimum	1980 Maximum	1979 n	1979 $\bar{x}$	1979 Minimum	1979 Maximum
YPZPOND1[2]	Water Level	100	4.4	..	24.9	2	..	21.3	22.8
	Temperature	15	9.3	3.3	17	..	..	..	..
	Conductivity	16	970	210	1950	..	..	..	..
	pH	15	7.5	7	8	..	..	..	..
YPZPOND2[2]	Water Level	100	1.0	..	2.63	1	..	..	25.6
	Temperature	5	11.2	9.5	14	..	..	..	..
	Conductivity	5	1875	1150	2400	..	..	..	..
	pH	5	7.1	7	7.2	..	..	..	..
YPZPOND3[2]	Water Level	99	0.2	..	21.5	..	..	..	..
YPZPOND4[2]	Water Level	101	1.9	..	15.6	2	..	15.95	19.3
	Temperature	18	9.5	3.3	19	..	..	..	..
	Conductivity	18	1751	910	3050	..	..	..	..
	pH	16	7.2	6.9	7.4	..	..	..	..
YJEFPOND	pH	5	8.0	8	8.1	..	..	..	..
	Temperature	5	13.8	11.5	16.1	..	..	..	..
	Conductivity	5	1390	1350	1450				

[1] Units: pH - pH units; temperature - °C; conductivity - µmhos/cm at 25°C; level - pond depth (ft); water level - depth to water (ft)

[2] Only nonzero (nondry) observations noted for water level evaluation

Table 5-45. Physical Data Summaries for Surface Flow Monitor Sites, Tract C-a

Station	Parameter[1/]	1980 n	1980 $\bar{x}$	1980 Minimum	1980 Maximum	1979 n	1979 $\bar{x}$	1979 Minimum	1979 Maximum
YBOXFL	pH	242	7.7	7.4	8.4	192	7.8	6.8	8.8
	Temperature	243	10.8	4.5	19	192	9.5	1.9	15.5
	Q	258	295.4	0.36	2500	243	258.2	85	1212
	Conductivity	243	1412	620	1800	183	1241	800	2250
YCULDIS	pH	178	8.0	7.6	8.6	140	8.1	7.3	9.0
	Temperature	179	8.2	1.5	18.8	141	17.1	10.3	23.5
	Q	179	9.8	7	13.8	..	..	..	..
	Conductivity	179	2072	1080	2250	140	1198	1000	1530
	TDS	..	..	..	..	40	1162	963	1414
YFLDIS	pH	28	8.2	7.2	8.9	13	8.2	7.9	8.6
	Temperature	29	16.3	9.4	20	13	16.8	11	19.5
	Conductivity	30	1555	1300	1900	13	1125	1060	1380
	TSS	15	21.4	5	62	..	..	..	..
	TDS	6	1029	1015	1087	..	..	..	..
YMET3	pH	194	7.7	7.4	8.5	61	8.2	7.7	8.9
	Temperature	195	11.2	5.9	18	61	10.2	4.6	17.3
	Conductivity	195	1426	1050	1700	61	1391	1090	1780
	TDS	60	1111	997	1195	60	1173	936	1525

Table 5-45. (Continued)

Station	Parameter[1]	1980 n	1980 $\bar{x}$	1980 Minimum	1980 Maximum	1979 n	1979 $\bar{x}$	1979 Minimum	1979 Maximum
YSEOFL	pH	328	7.8	7.5	8.5	192	7.8	7.0	8.8
	Temperature	315	10.0	..	18.5	195	8.9	3.1	14
	Q	300	350.8	0.54	1553	246	1055	597	2250
	Conductivity	330	2053	1130	2350	185	2063	870	2500
Y24RDN	pH	2	..	8	8	5	7.6	7.4	8.0
	Temperature	2	..	10	18	5	9.3	5	14
	Q	120	0.008	..	0.5	146	4.2	..	12.7
	Conductivity	2	..	1850	1850	5	2254	2170	2450
Y24RDS	pH	149	8.0	7.7	8.5	113	8.3	7.2	9.5
	Temperature	149	12.8	1	22	116	8.8	0.9	16.5
	Q	152	0.50	..	0.52	234	9.7	3.6	15.1
	Conductivity	149	1904	1700	2250	114	1940	1490	2280
YLDGEDGE	pH	..	..	..	..	5	7.6	7.6	7.6
	Location	335	0.89	..	2	212	1.5	..	1.65
	Conductivity	..	..	..	..	4	2250	2175	2400

[1] Units: pH - pH units; temperature - °C; Q - flow, gpm; conductivity - µmhos/cm at 25°C; TSS - total suspended solids, mg/l; TDS - total dissolved solids, mg/l; location - miles

Table 5-46. Physical Data Summaries for Dewatering/Reinjection Monitor Sites, Tract C-a

Station	Parameter[1/]	1980				1979			
		n	$\bar{x}$	Minimum	Maximum	n	$\bar{x}$	Minimum	Maximum
YCOINJ	pH	298	8.0	7.3	8.8	..	..	..	..
	Temperature	298	14.8	9.1	19	..	..	..	..
	Conductivity	298	1387	1200	1500	..	..	..	..
	TSS	179	34.7	2	154	..	..	..	..
	TDS	179	1013	943	1087	..	..	..	..
GS-D1U	Q	144	44	..	57.23	..	..	..	..
GS-D5U	Temperature	19	17.8	16	20	20	16.4	12.7	19.5
	Conductivity	19	1326	1225	1450	20	1226	1010	1450
	pH	19	7.7	7.4	8.0	20	8.0	7.6	8.5
GS-D6U	Temperature	31	16.2	11	19	..	..	..	..
	Conductivity	31	1343	1150	1500	..	..	..	..
	pH	31	7.6	7.3	8	..	..	..	..
GS-D7U	Q	238	59.3	..	185.8	..	..	..	..
GS-D8U	Q	22	213.4	211.2	214.3	..	..	..	..
	Temperature	81	14.8	12.7	20	..	..	..	..
	Conductivity	81	1358	1200	1500	..	..	..	..
	pH	81	7.9	6.8	8.4	..	..	..	..
	TDS	32	993	925	1015	..	..	..	..
	TSS	29	3.6	1	1	..	..	..	..
GS-D9U	Q	237	89.9	..	277.3	..	..	..	..

[1/] Units: pH - pH units; temperature - °C; conductivity - µmhos/cm at 25°C; TSS - mg/l; TDS - mg/l; Q - flow, gpm

Four piezometers (YPZPOND1 through YPZPOND4) have been installed near the East and West Retention Ponds to monitor any seepage from the ponds. In September and October 1979, all piezometers were dry. However, beginning in November 1979, water was observed in three piezometers (all but YPZPOND3). This was felt to be due to precipitation and not to seepage from the ponds. This conclusion seems borne out by the fact that all piezometers were again dry by the end of the 1980 report year.

Stations YFLDIS and YCULDIS measure direct discharges at the West Retention Pond overflow flume and at the Visitor's Center culvert, respectively. Conductivity at these two discharge stations was generally greater during the 1980 report year than was observed during 1979. Values of pH and water temperature were comparable to 1979 levels.

Surface flow monitor sites included in the development activities monitoring program reflect both natural flow and discharges from operation.

Flow at the Box Elder Flume (YBOXFL) shows primarily a response to spring runoff (Figure 5-20). This station had exhibited a slight increase in base flow at the end of the 1979 report year. This trend was attributed to increasing reinjection pressures. This increasing trend was not observed in the second half of the 1980 report year. The 1980 pattern of discharge at YBOXFL was also reported at the State Engineers Flume (YSEOFL). The low discharges recorded late in 1980 reflect the decreased frequency of dewatering discharges to the surface during 1980. The 1980 report year measurements of pH, temperature, and conductivity at these and other flow monitor sites were comparable to 1979 measurements (Table 5-45).

The location of the "leading edge" (YLDGEDGE) is the distance downstream from the 24-Road Crossing where the stream disappears. These data also reflect diminished surface discharges during 1980 (Figure 5-21). The location in the early part of 1980 is comparable to 1979 data (about 1.5 miles) but decreases to less than 0.25 mile in mid-1980. The conductivity of composite reinjection water was somewhat variable during the 1980 report year (Figure 5-22), but no real trends are apparent. No temporal trends were apparent for pH, TDS, or

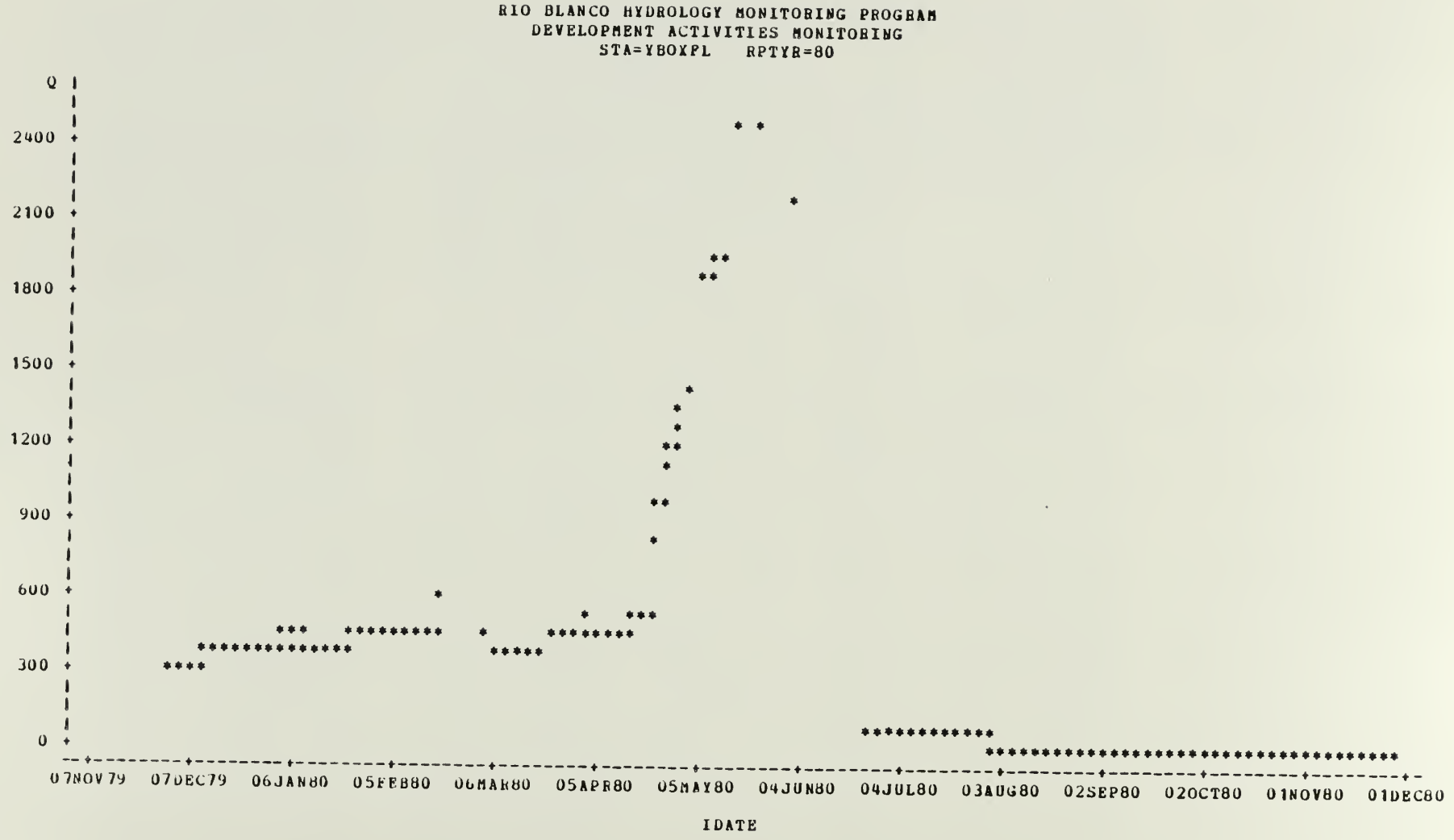


Figure 5-20. 1980 Report Year Discharge (Q, gpm) data, Box Elder Gulch Flume (YBOXFL), Tract C-a

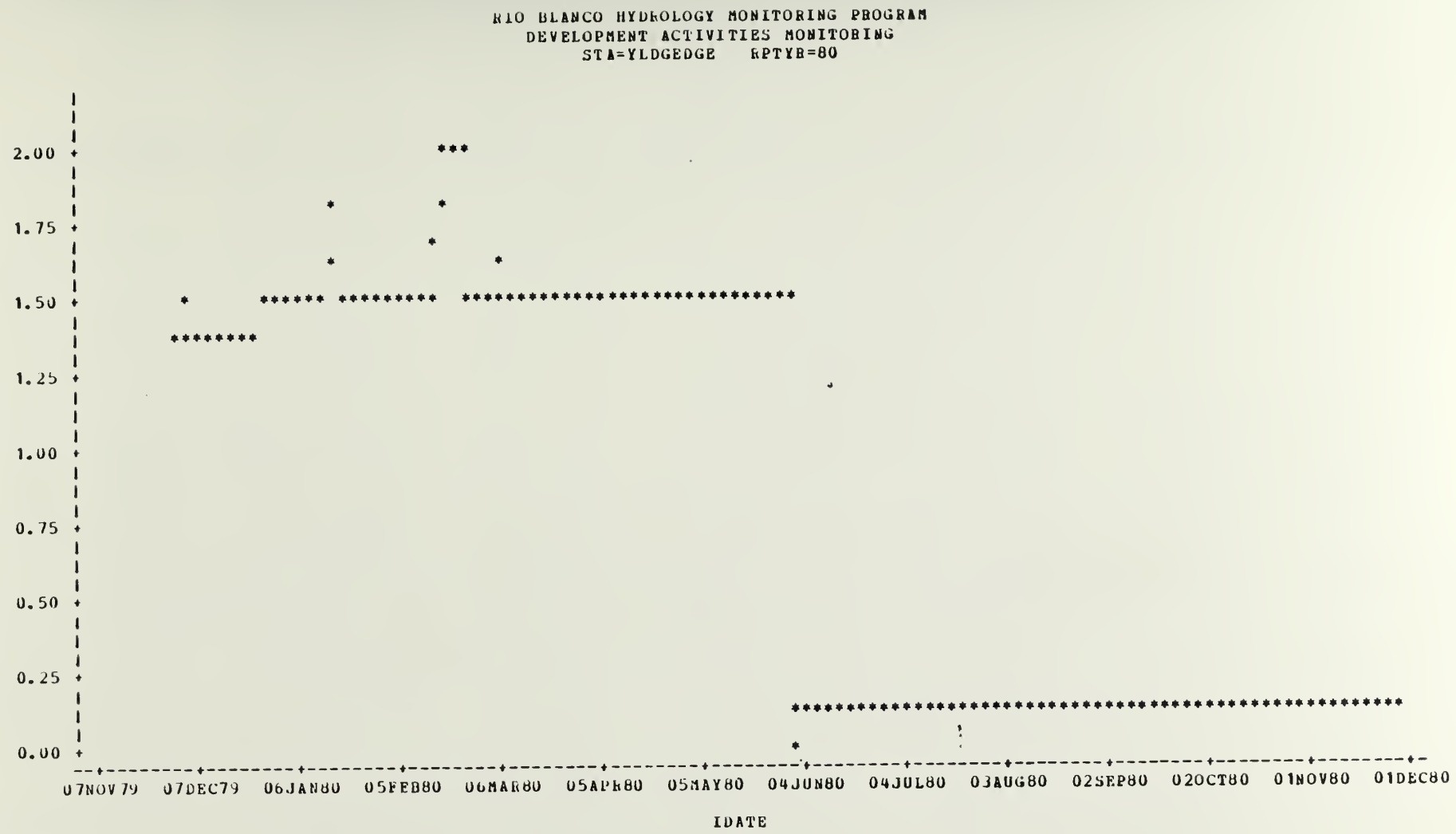


Figure 5-21. 1980 Report Year Location of Leading Edge of Flow in Yellow Creek (miles below 24 Road Crossing), Tract C-a

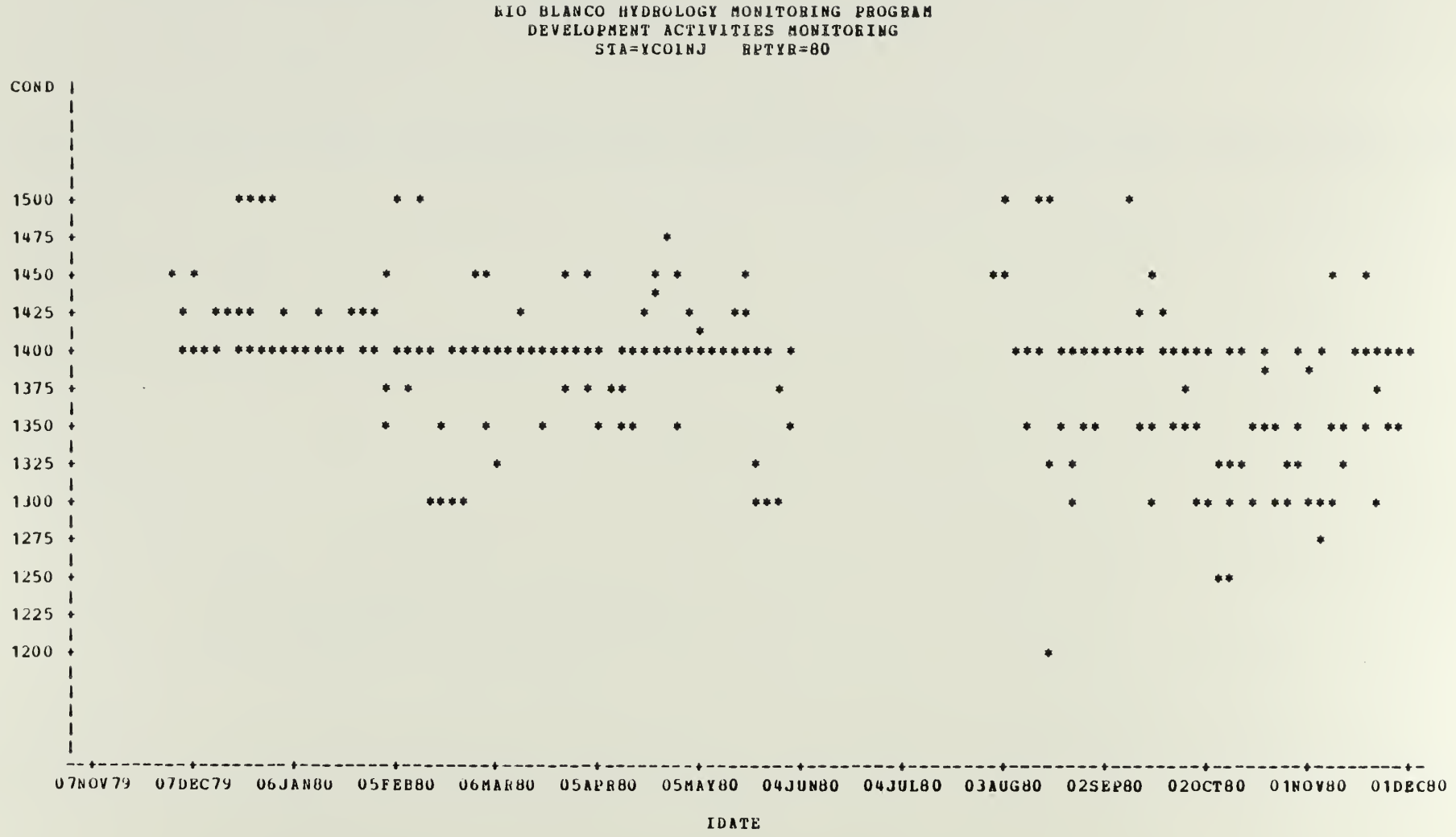


Figure 5-22. 1980 Report Year Specific Conductance (COND, µmhos/cm at 25°C) Data for Composite Reinjection (YCOINJ) Water, Tract C-a

TSS during 1980. Temperatures rose steadily during the 1980 report year from about 9 to about 18°C in August and then declined slightly through the end of the report year (Figure 5-23).

Data on dewatering wells were fairly consistent among this set of monitor sites (Table 5-46). Conductivity was usually in the 1200- to 1400-µmhos/cm range and pH was most commonly 7.5 to 8.0. When discharging, discharge rates are fairly constant (Appendix 5-3.1).

Maximum level observations of water chemistry constituents for the 1979 and 1980 report years are listed in Table 5-47. These and other water quality data are tabulated in Appendix 5-3.2. Only maximum levels are compared here because of the small sample size ($n \leq 3$) for the 1979 report year.

The water quality (considering maximum observed concentrations) of the composite reinjection stream for 1980 was generally comparable to that observed for the 1979 report year. The 1980 maxima for specific conductance, pH, and the concentrations of most major inorganic ions were slightly above 1979 values. The 1980 maximum TDS level (1788 mg/l) may be anomalous; the next lower concentration is 1050 mg/l.

Similar general conclusions are applicable to data for Well GS-D5U. Here the 1980 maximum DOC concentration (84 mg/l) may be in error due to laboratory analysis problems. Other DOC observations for the 1980 report year were 25 and 6 mg/l.

The water quality of the retention ponds is much more variable than many other development activities monitoring sites. The 1980 report year data maxima were, however, comparable to 1979 observations (Table 5-47). The 1980 maximum DOC concentration of 220 mg/l is probably due to erroneous analysis. The next lower reported concentration was 8.1 mg/l.

The cone of depression resulting from dewatering operations is shown in Figures 5-24 and 5-25. The -200- and -100-foot contours were only slightly

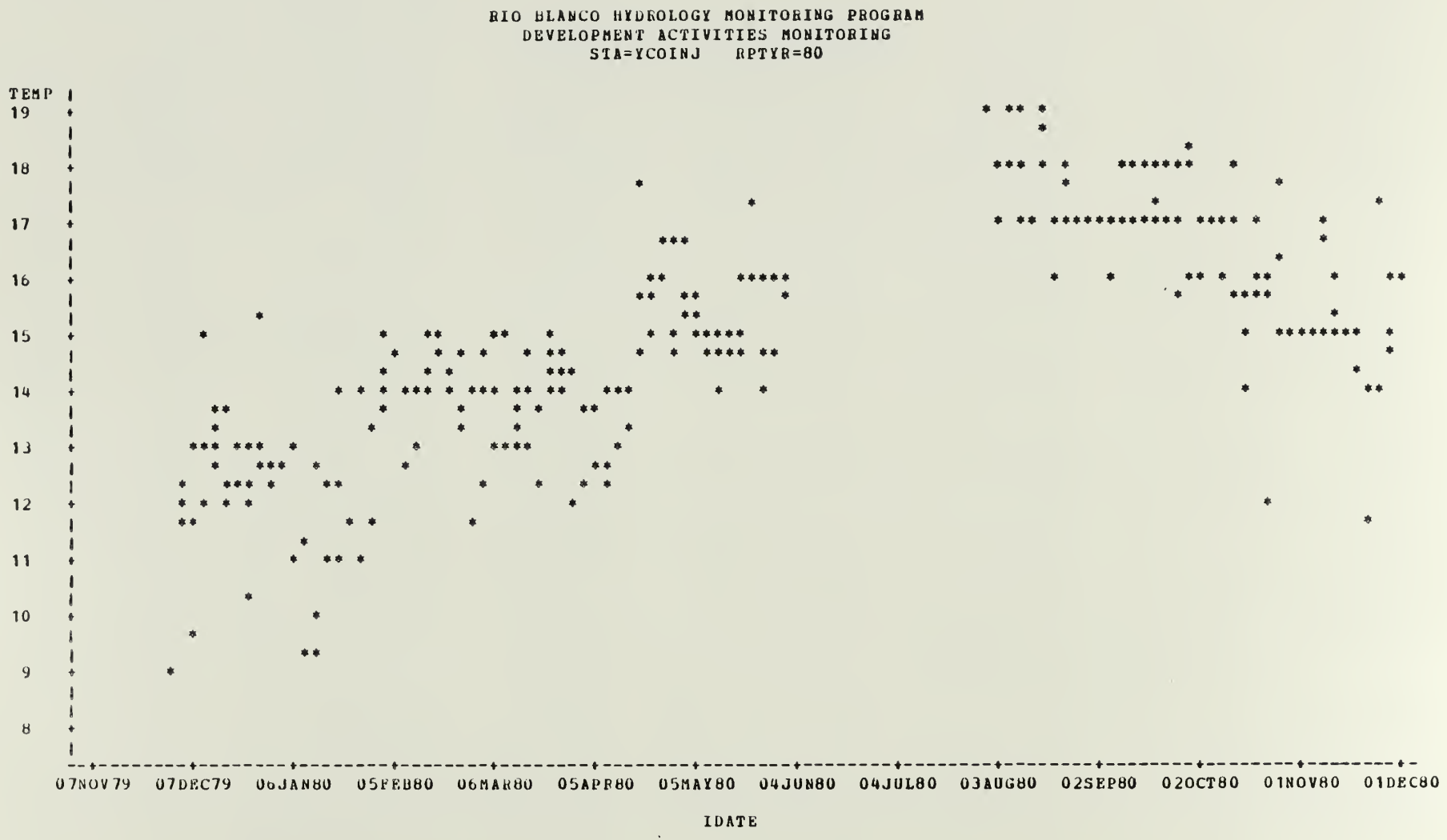


Figure 5-23. 1980 Report Year Water Temperature (TEMP, °C) Data for Composite Reinjection (YCOINJ) Water, Tract C-a

Table 5-47. Comparison of 1979 and 1980 Report Year Maxima for Composite Reinjection Water (YCOINJ), Well GS-D5U, and the East and West Retention Ponds (YERPOND and YWRPOND)

Parameter[1/]	YCOINJ Maxima		GS-D5U Maxima		YERPOND Maxima		YWRPOND Maxima	
	1980	1979	1980	1979	1980	1979	1980	1979
Specific Conductance	1500	1400	1425	1280	1960	1700	1400	1460
pH	8.4	8.0	8.5	7.9	10.4	9.7	9.0	8.5
Alkalinity	488	443	584	490	386	402	494	407
HCO_3	587	536	686	575	284	451	571	468
CO_3	20	..	24	22	90	41	72	30
Ca	80	43	64	37	21	29	56	37
Mg	97	75	74	76	60	63	71	79
Na	220	200	287	180	388	245	230	280
K	1.3	2.0	2.3	5.0	9.5	8.0	2.3	3.0
Cl	13.6	8.0	24	14	157	178	18	76
SO_4	388	350	353	285	642	300	379	350
F	1.8	2.2	1.6	1.5	2.2	1.3	1.8	1.9
As	<0.01	..	<0.01	<0.01	0.02	<0.01	<0.01	<0.01
B	0.71	0.16	0.60	0.19	0.24	0.2	0.2	<0.1
Mo	..	..	..	..	<0.1	..	..	..
V	..	..	..	..	<0.5	..	..	..
Se	<0.01	..	<0.01	<0.01	0.02	<0.01	<0.01	<0.01
Hg	<0.001	..	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
DOC	11	..	84	<1	220	<1	11	<1
TDS	1788	..	1016	868	1432	..	996	909

[1/] Units: specific conductance - µmhos/cm at 25°C; pH - pH units; all other - mg/l

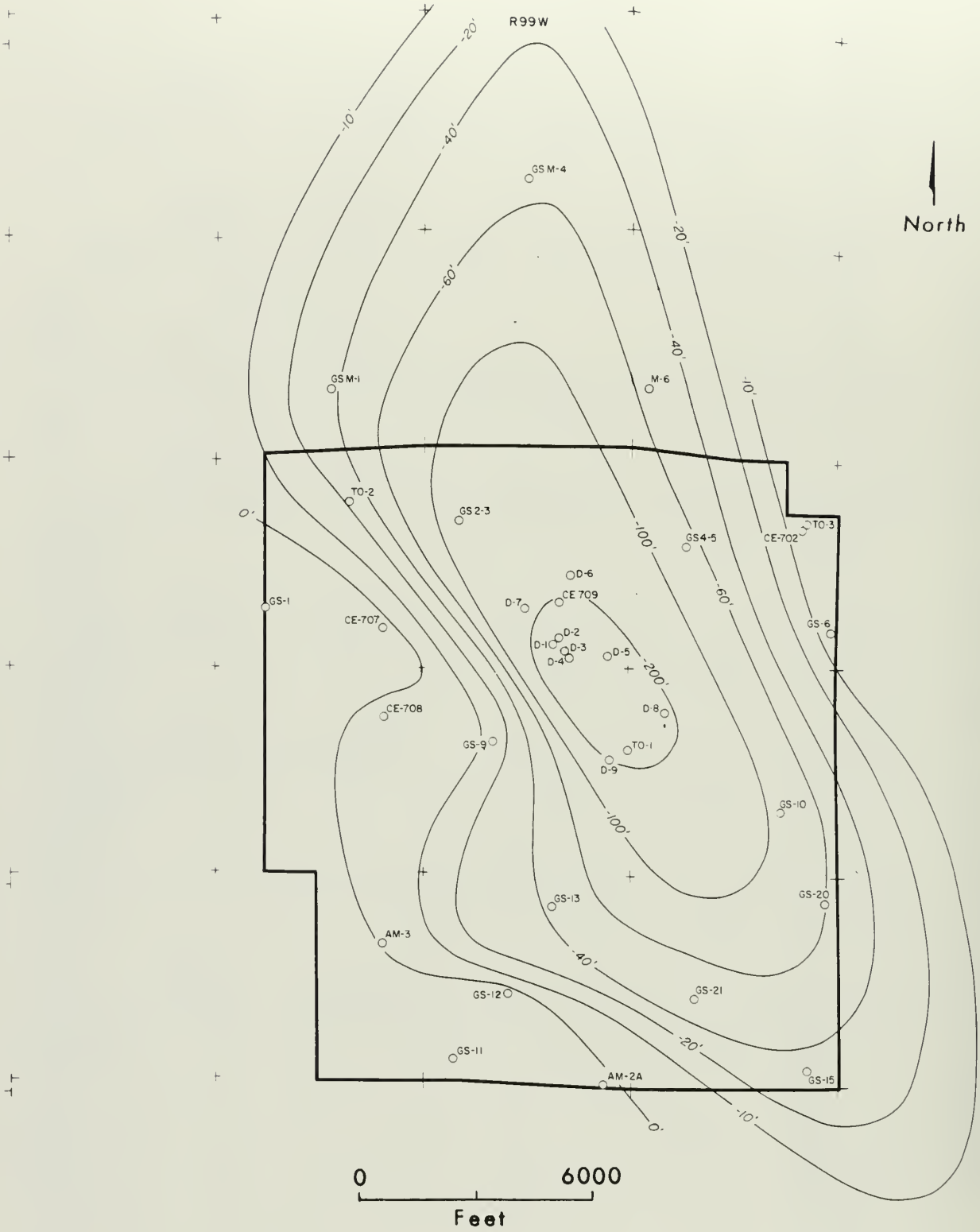


Figure 5-24. Upper Aquifer Cone of Depression January, 1980

Figure 5-25. Upper Aquifer Cone of Depression October 15, 1980

changed over the 1980 report year. The -200-foot contour was somewhat larger and the -100-foot contour somewhat smaller in October 1980 than in January 1980. In general, the cone of depression was very similar in both January and October 1980.

The operation of the dewatering program is summarized in Figures 5-26 through 5-32. Total water production is shown in Figure 5-26. Total discharge from dewatering wells increased from 400 to 600 gpm in the Spring to 800 to 1000 gpm in the May-through-September period (Figure 5-27). Discharges were then diminished to less than 400 gpm in November and December 1980. Mine flow (Figure 5-28) showed a pattern opposite from that of the dewatering wells with discharges of 1200 to 1300 gpm at the beginning and end of 1980 and decreased flows (~1000 gpm) in the mid-year period.

Consumptive uses of water generally increased through 1980 (Figure 5-29) from less than 100 gpm in January to generally over 600 gpm in December. Peak use of over 1000 gpm occurred in November 1980.

Water not consumed is either reinjected or discharged to surface streams. The total flow disposed of is shown in Figure 5-30. Although quite variable over the year, these flows generally increased from about 1600 gpm in January to over 2000 gpm in December 1980. Surface disposal was infrequent during 1980 (Figure 5-31). Short-term (a few days) discharges were made in January, February, and December 1980. Longer-term (a few weeks) discharges were made in May through June and in August. The majority of water was reinjected (Figure 5-32). Reinjection flows of 1200 to 1600 gpm were generally maintained throughout 1980.

TOTAL WATER PRODUCTION

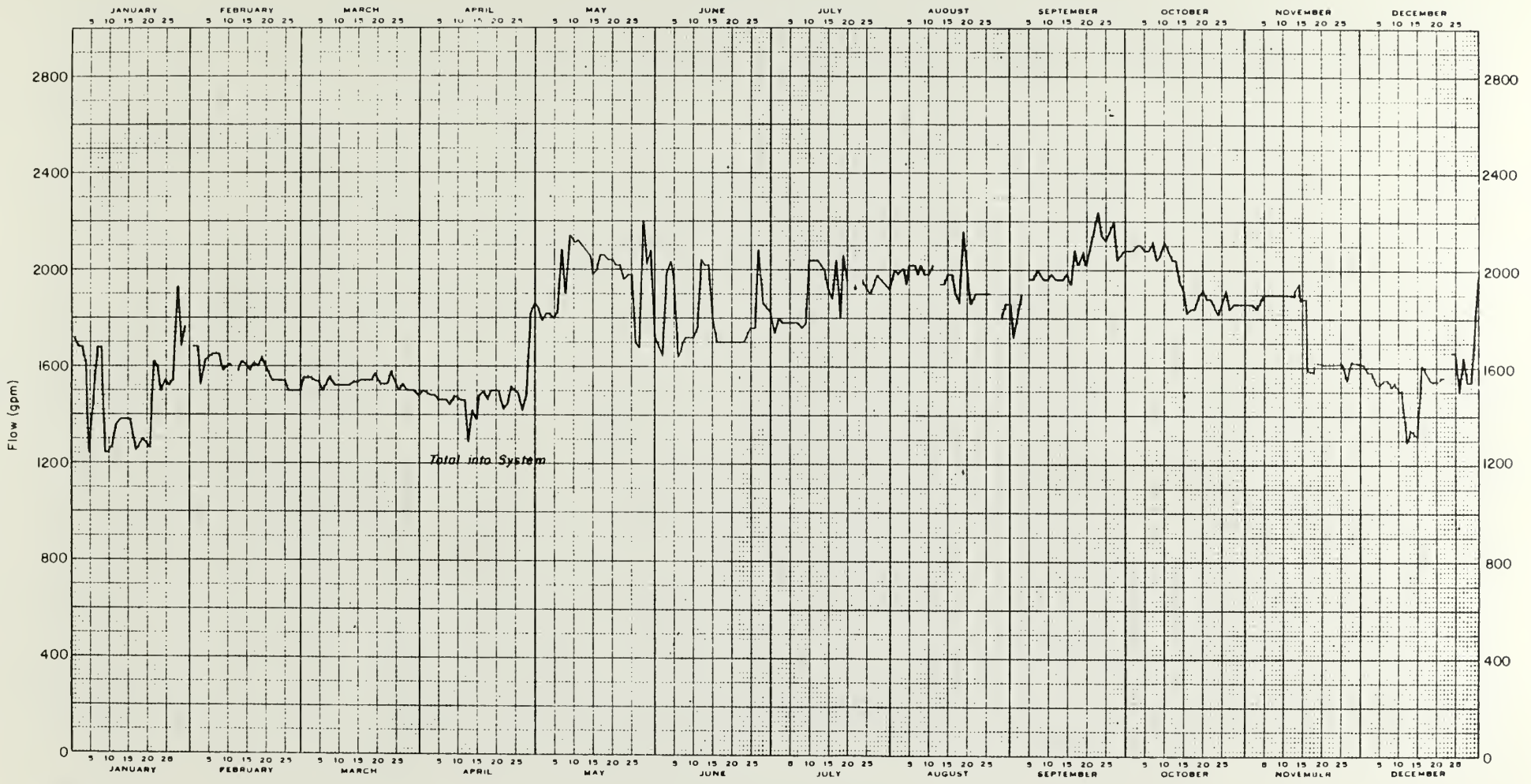


Figure 5-26

TOTAL OF DEWATERING WELLS

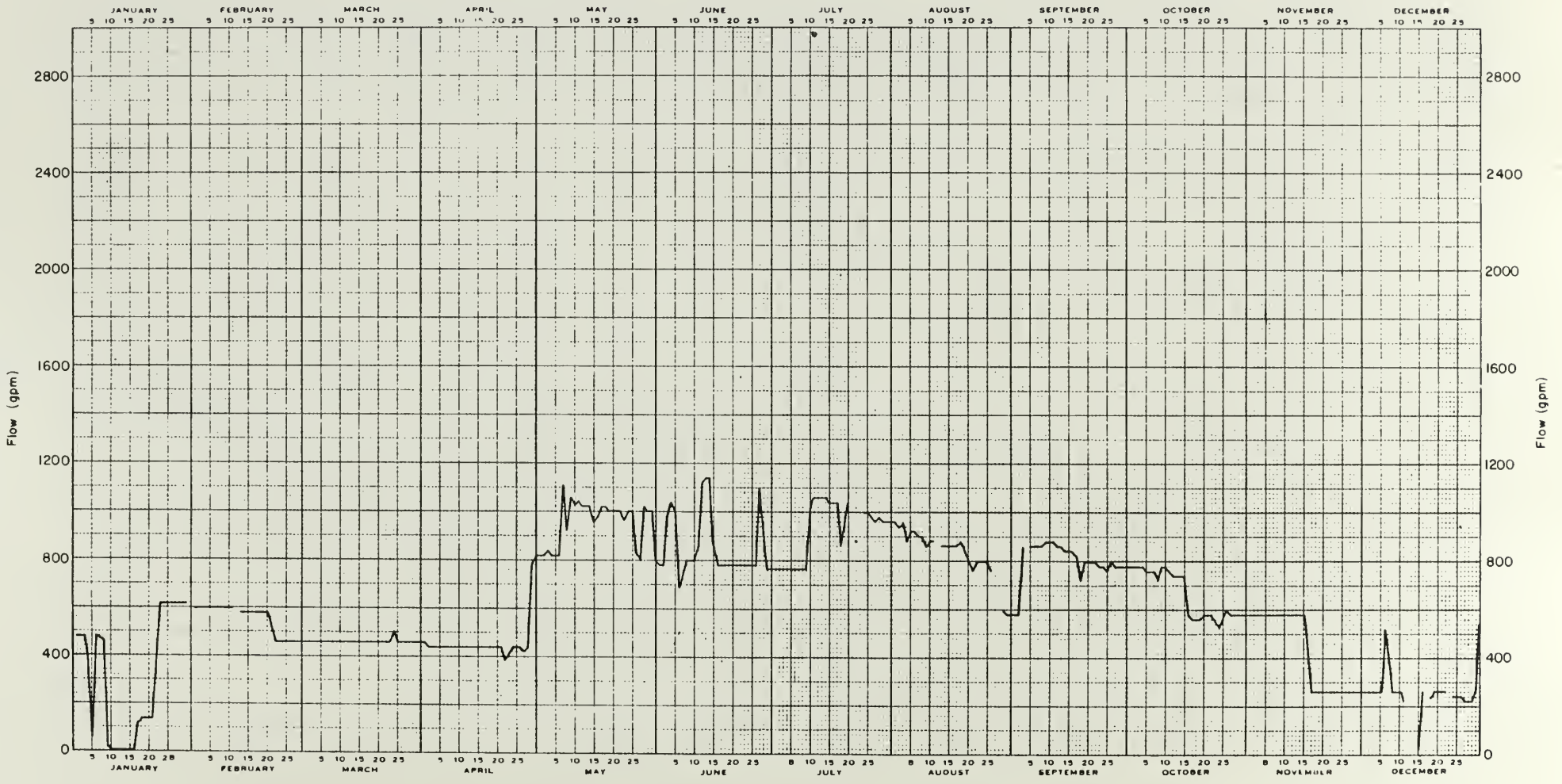


Figure 5-27

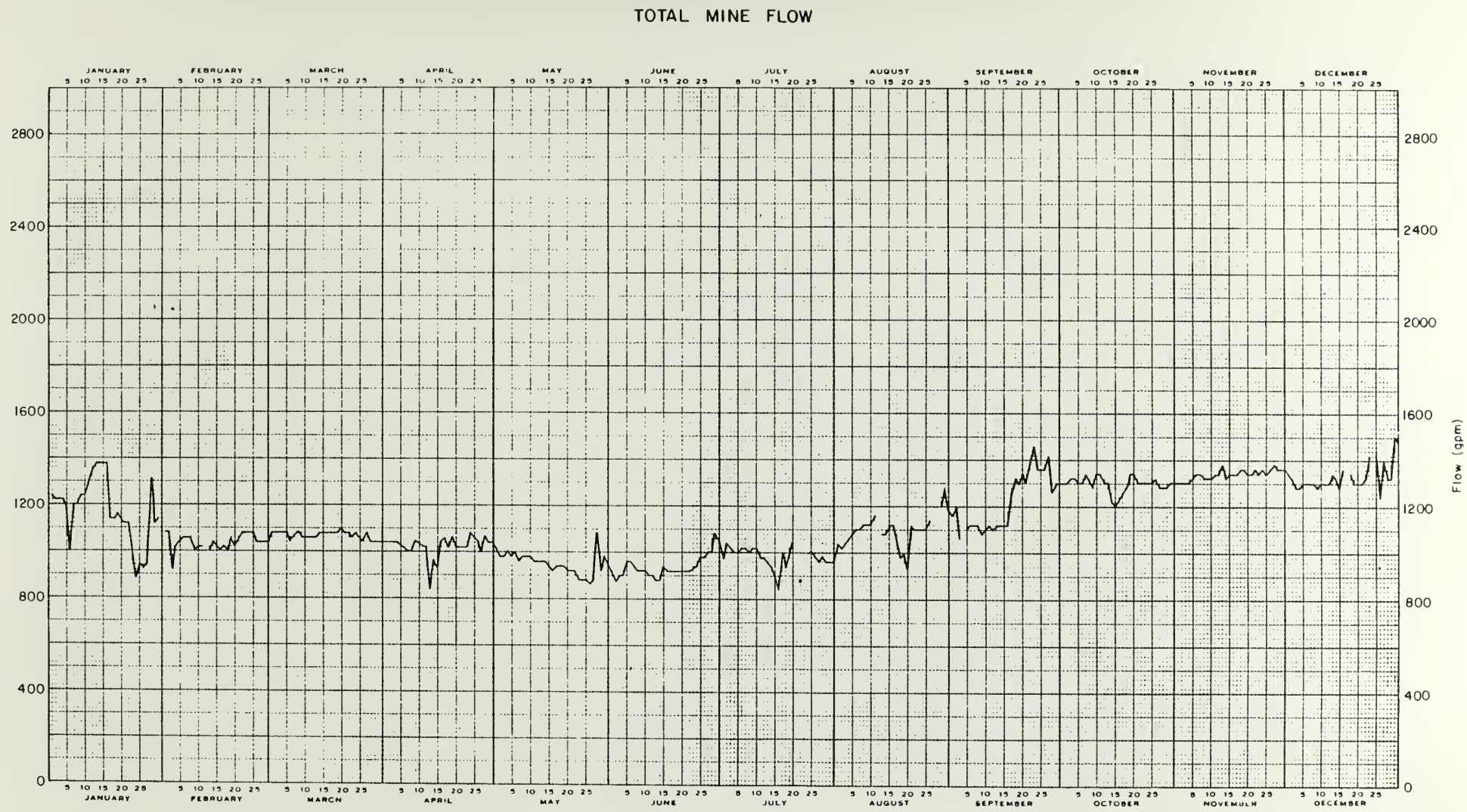

TOTAL MINE FLOW
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
Flow (gpm)
0
400
800
1200
1600
2000
2400
2800

Figure 5-28

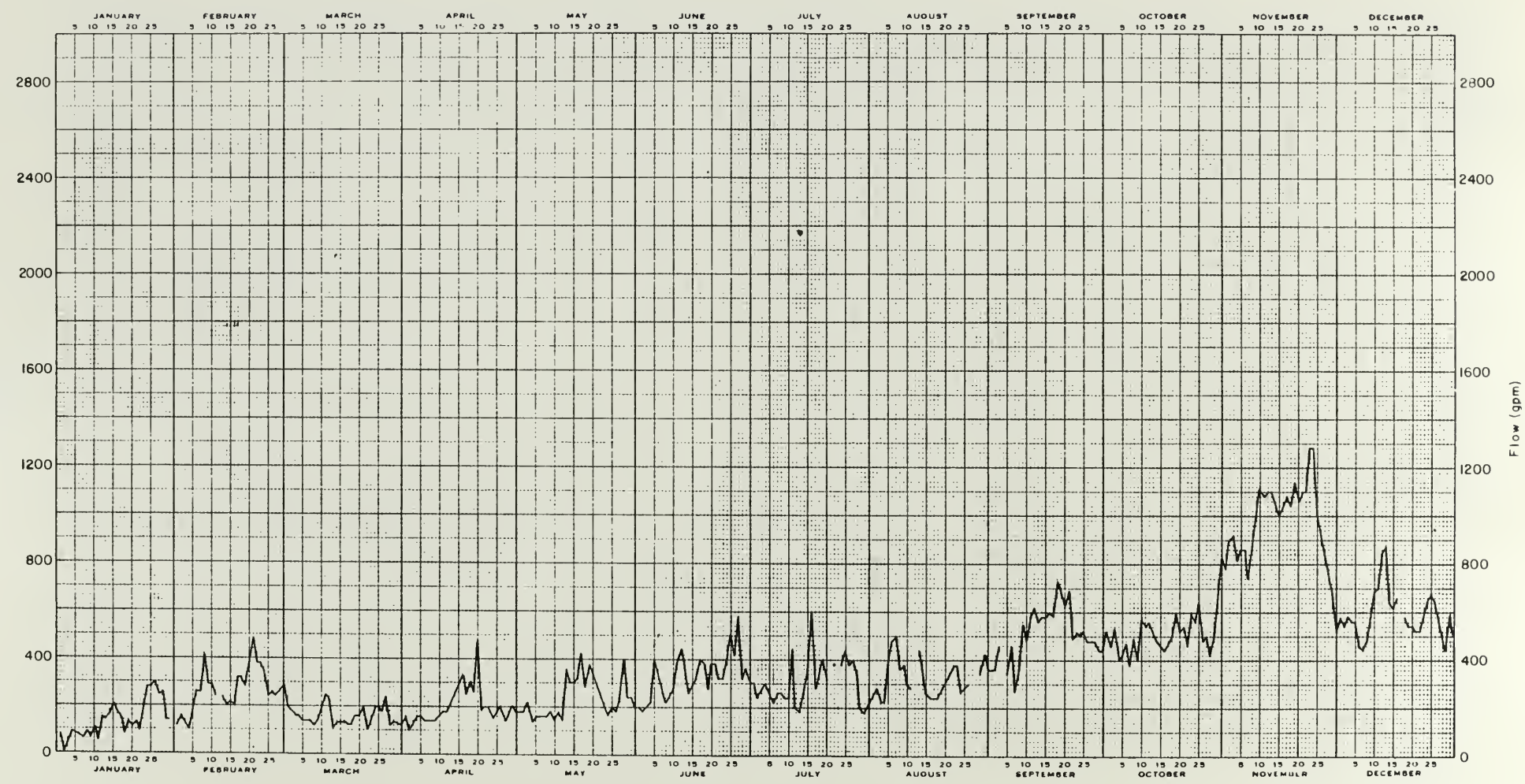

CONSUMPTIVE USE
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
5 10 15 20 25
2800
2400
2000
1600
1200
800
400
0
Flow (gpm)

Figure 5-29

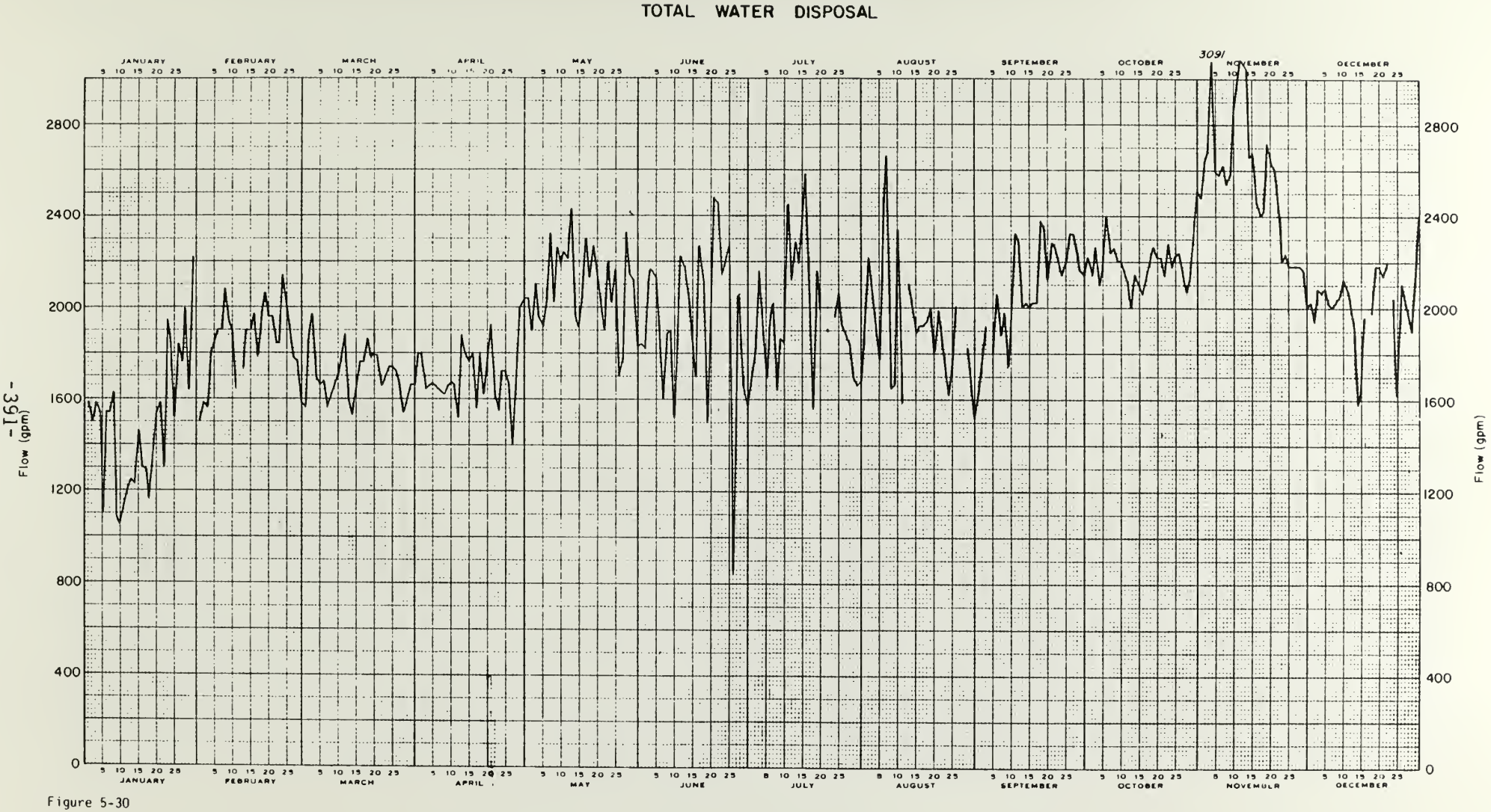

TOTAL WATER DISPOSAL
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
3091
2800
2400
2000
1600
1200
800
400
0
Flow (gpm)

Figure 5-30

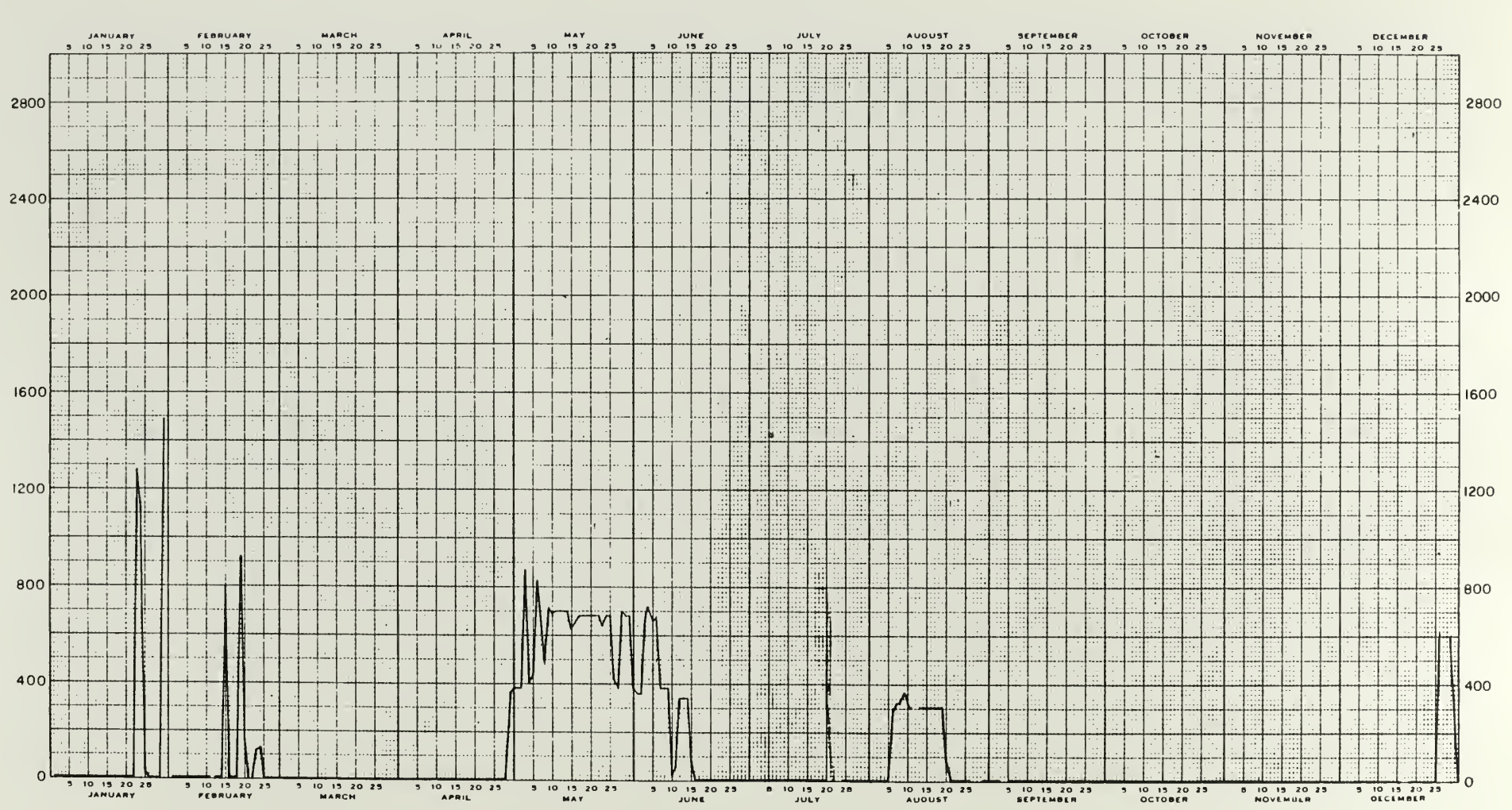

SURFACE DISCHARGE
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
5 10 15 20 25
0
400
800
1200
1600
2000
2400
2800

Figure 5-31

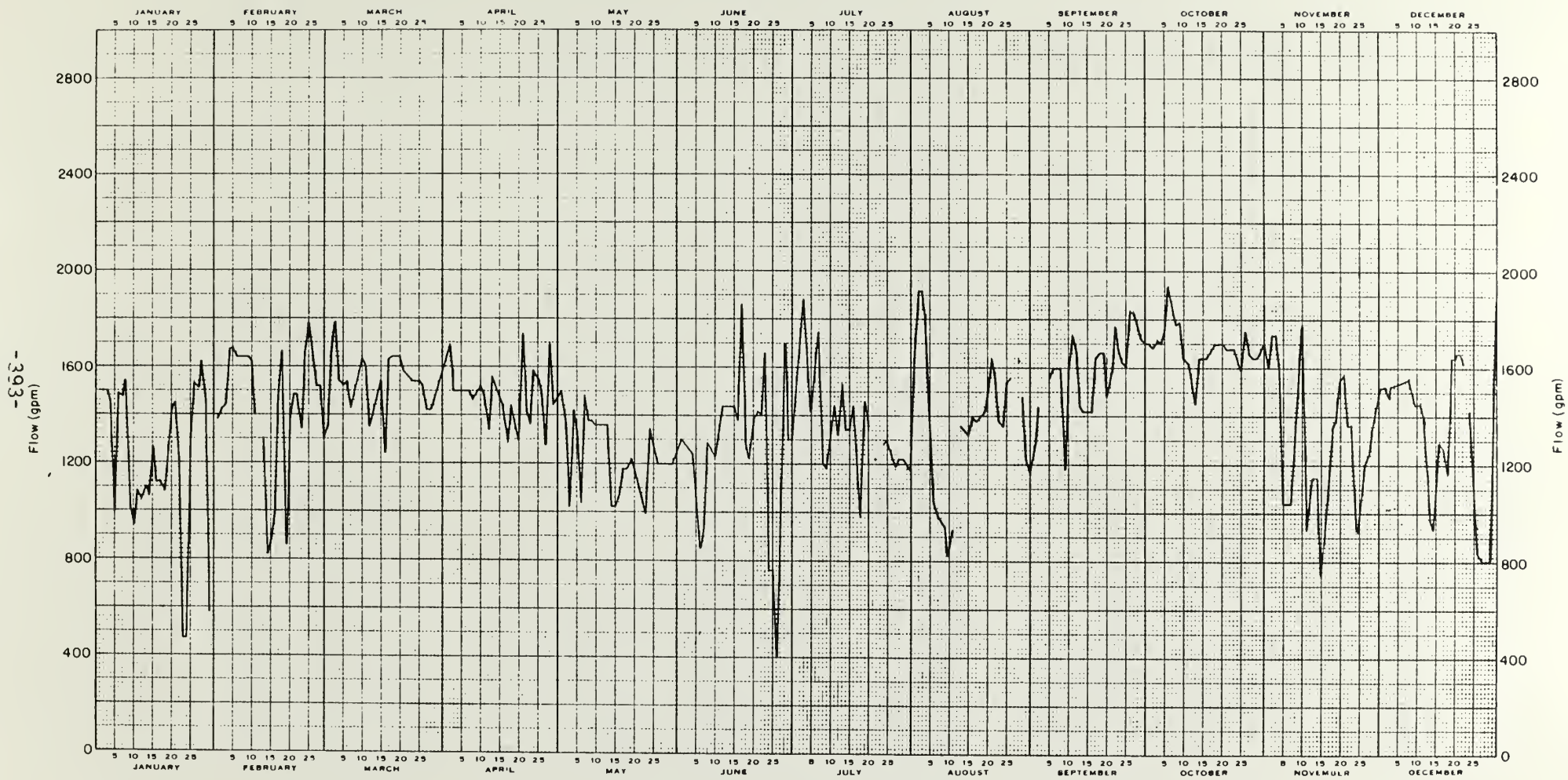

TOTAL REINJECTION
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
Flow (gpm)
0
400
800
1200
1600
2000
2400
2800

Figure 5-32

5.4 SUMMARY

The hydrology monitoring program produces information applied to several needs:

- Stipulations of the lease and conditions of approval from the OSO
- Engineering design input for mine and water handling systems
- Evaluation of the need for environmental mitigative measures
- Permit requirements

Data on surface streams and groundwater have been collected since 1975. The 1980 report year data have been compared to data from previous years to identify and to evaluate any trends. The program includes monitoring at numerous installations, including stream gaging stations, springs and seeps, erosion and sedimentation stations, alluvial and deep aquifer wells, surface impoundments, surface discharges, reinjection system, and dewatering wells. The natural hydrologic and hydrogeologic environment is monitored as well as facilities associated with oil shale activities.

Six USGS stream gaging stations were included in the 1980 monitoring program. Continuous monitor data (flow, specific conductance, pH, and temperature) for 1980 were not available from USGS for this report. Water quality data were available for all but the Dry Fork Station (A).

When compared to the baseline period, differences in water quality observed in 1980 were generally not appreciable, particularly for mean values. Differences noted in specific conductance and concentrations of several major inorganic ions and dissolved organic carbon (DOC) in Corral Gulch (east of tract) may be related to occasional mine water discharges in the Corral Gulch watershed. Similar differences from the baseline were noted in the year-end report for 1979. Multiple analysis of variance (MANOVA) indicated that surface flow water quality data for the 1980 water year was significantly different from the baseline only for concentrations of molybdenum and DOC.

Springs and seeps data for 1980 were generally comparable to previous observations. Baseline data on water chemistry collected near the existing sampling sites are presently being evaluated for comparison with current data.

Data collected at alluvial wells showed seasonal patterns comparable to earlier observations. Analysis of physical data showed a general increasing trend in pH since the baseline period. Data reported in 1980 were comparable to 1979 observations. The trend in pH is probably due to several factors, including natural variability, sampling errors, and the discharge of upper aquifer water into the alluvial system. The presently observed slightly alkaline conditions are characteristic of western arid regions and the overall magnitude of the change is small.

Statistical analysis of alluvial water quality data showed significant differences between 1980 and baseline years for several constituents. However, with the exception of specific conductance, pH, and magnesium concentration, the overall mean levels during the baseline were greater than the means for 1980. Similar results were noted in the year-end report for 1979.

Upper aquifer data showed increased pH levels and slightly increased conductivity levels since the baseline period. Similar trends were observed for the lower aquifer. Statistical analysis of upper aquifer water quality data indicated that the 1980 report year was significantly different from the baseline for several constituents. However, the 1980 means were less than baseline year means for all of these except pH, calcium, magnesium, and sulfate. The pH in the lower aquifer was also shown to be significantly greater than baseline pH levels.

Several factors (e.g., natural variability, sampling errors, local changes in aquifer chemical equilibria influenced by the presence of wells, and perhaps general equilibria changes due to dewatering) interact to create the observed changes in the upper aquifer. The changes are considered to be geochemical in nature and not the results of retorting or other development impacts.

Development activities were directly monitored using installations associated with the dewatering/reinjection/discharge system, runoff collection system, and liquid waste impoundments. Where past data on ponds were available, 1980 observations were generally comparable to past observations. The piezometers used to monitor pond seepage were dry by the end of 1980, supporting the conclusion that water previously observed in these was due to natural infiltration from precipitation and not pond seepage.

Surface flow stations during 1980 generally reflected discharges lower than 1979 due to diminished surface discharge from the dewatering system. Conductivity, temperature, and pH levels during 1980 were generally comparable to earlier measurements.

The cone of depression resulting from the dewatering operations was relatively constant throughout 1980. Most of the mine water and discharge from dewatering wells was reinjected during 1980.

SECTION 6
SPECIAL STUDIES

6.1 TOXICOLOGY

1. Objectives

Toxicology studies have been or are being conducted to assess the potential health hazard of oil shale-related emissions, effluents, solid wastes, products and combustion products. Specifically, these studies are designed to accomplish the following tasks:

- Characterize the chemical and physical properties of the raw shale, and the products and by-products from the retorting processes, to determine the potential hazard of these materials

- Determine the biological activity (carcinogenicity, mutagenicity, teratogenicity, and toxicity) of oil shale products and by-products

- Assess the potential worker exposures and environmental hazards

- Provide data to aid in the development of an industrial hygiene program, control procedures and technology to mitigate or prevent worker exposure and environmental hazards

2. Methods

a. API Program - In 1976, the American Petroleum Institute (API) initiated a program to investigate selected toxicological properties of oil shale and related materials. This study included evaluating the acute toxicity, chronic inhalation toxicity, carcinogenesis, mutagenesis and teratogenesis of raw shale, raw shale oil and processed shale. Samples for these tests were collected from oil shale properties throughout the Colorado Plateau and included samples of raw shale from Tract C-a. A detailed discussion of the API program has been published in the American Industrial Hygiene Association Journal (Weaver and Gibson 1979).

b. DOE Program - A Department of Energy (DOE) sponsored toxicology program was initiated in 1980 to collect more detailed, site-specific toxicology data at Tract C-a on raw oil shale and the products and by-products generated by the MIS processing of this shale. These studies included the following:

- Detailed chemical and physical characterization of the source materials, process streams, products and by-products
- Evaluation of potential health effects associated with MIS processing of oil shale
- Biological testing of the compounds and materials associated with the MIS extraction procedure

3. Results

a. API Program - The first phase of the API studies has been completed, and the results have been published (Weaver and Gibson 1979). In the inhalation studies, rats and monkeys exposed to either raw or processed shale dust at concentrations of 10 and 30 mg/m^3 each for 2 years showed no evidence of carcinogenesis or progressive fibrotic lung disease from either material. Dermal application of raw and processed shales resulted in no evidence of carcinogenicity when applied to mice at a dosage of 50 mg twice weekly for a lifetime (approximately 2 years). Similar tests using raw shale oil showed, however, that the raw oil was highly carcinogenic. Tests using refined and semi-refined products were initiated in August 1979. Results of these tests are not available presently but it is anticipated that the refining steps will significantly reduce the carcinogenic and toxic properties of the raw shale oil (Weaver and Gibson 1979).

Tests of raw and processed shale, and crude shale oil to determine teratogenic effects on pregnant rats showed no deformities, although some fetal toxicity was seen in rats exposed to the higher dosages of crude retort oil tested.

All of the raw shale oil samples yielded positive results for mutagenicity in the bacterial assays (Ames test), were either weakly positive or negative for mutagenicity in the mouse lymphoma assay, and showed no mutagenic tendencies in the cytogenetic bioassay.

Results of the studies on acute toxicity, irritation and sensitization are summarized in Table 6-1. Histopathological studies of the test organisms exposed to toxic concentrations of crude shale oils revealed extensive liver damage resulting from both oral and dermal administration of the oil.

Table 6-1. Summary of Results from Acute Studies Conducted by the API

Test	Material	Number of Samples	Results
Acute Oral Toxicity (Rat)	Crude Shale Oils	(4)	Oral LD_{50} = 8-10g/kg[1/]
Acute Dermal Toxicity (Rabbit)	Crude Shale Oils	(4)	Dermal LD_{50} = 5-20ml/kg[2/]
Eye Irritation (Rabbit)	Crude Shale Oils	(4)	Minimal/reversible Effects
	Oil Shales (Ore)	(3)	No Negative Effects
	Processed shales	(4)	Irritating/reversible Effects
Dermal Irritation (Rabbit)	Crude Shale Oils	(4)	Positive at 0.5g/72 hrs for Abraided and Unabraided Condition
Skin Sensitization (Guinea Pig)	Crude Shale Oils	(4)	
	Oil Shales (Ore)	(3)	No Negative Effects
	Processed Shales	(4)	

[1/] LD_{50} = Dosage at which 50 percent of test animals expire
[2/] Not firmly established

b. DOE Program - The tests conducted under the DOE Toxicology Program have been completed, but the results are not available as yet. These results will be reported by the DOE Oil Shale Task Force.

6.2 REVEGETATION

A. Experimental Revegetation Studies of Surface Disturbed Sites

1. Objectives

The development of oil shale facilities on Tract C-a will result in distu ed lands which will be revegetated once disturbance ceases. Experiments were initiated during 1975 to demonstrate reclamation feasibility and species adaptability with varying mulch types, fertilizer applications, and plot aspects.

2. Methods

Experiments were conducted on two plots located in the southeast corner o Tract C-a, with plot R-1 being located on a northwest exposure and R-2 on southeastern exposure. Surface disturbance at each site included strippi topsoil and subsoil, ripping the underlying rock substrate, and then repla ing subsoil followed by topsoil. Subsequent to these activities the sites we seeded, mulched, and/or fertilized using a total of 16 treatment combinat ns, with three replicates of each treatment applied at each site in a randomiz d block design. Additional information on methods is presented in Section 2.5.3.2 of Progress Report 4 (RBOSP 1975) and in Revegetation Annual Repor s (RBOSC 1977, 1978, 1979a). Cover estimates were not made during 1979 (the year after clipping) on either R-1 or R-2.

3. Results and Discussion

a. Experimental Revegetation Plot R-1 - Coverage on R-1 plots was assessed between August 12-15, 1980. These data are summarized in Table 6 2 and presented in their entirety in Appendix 6-2.1. The configuration of treat ent combinations for plot R-1 is illustrated in Figure 6-1.

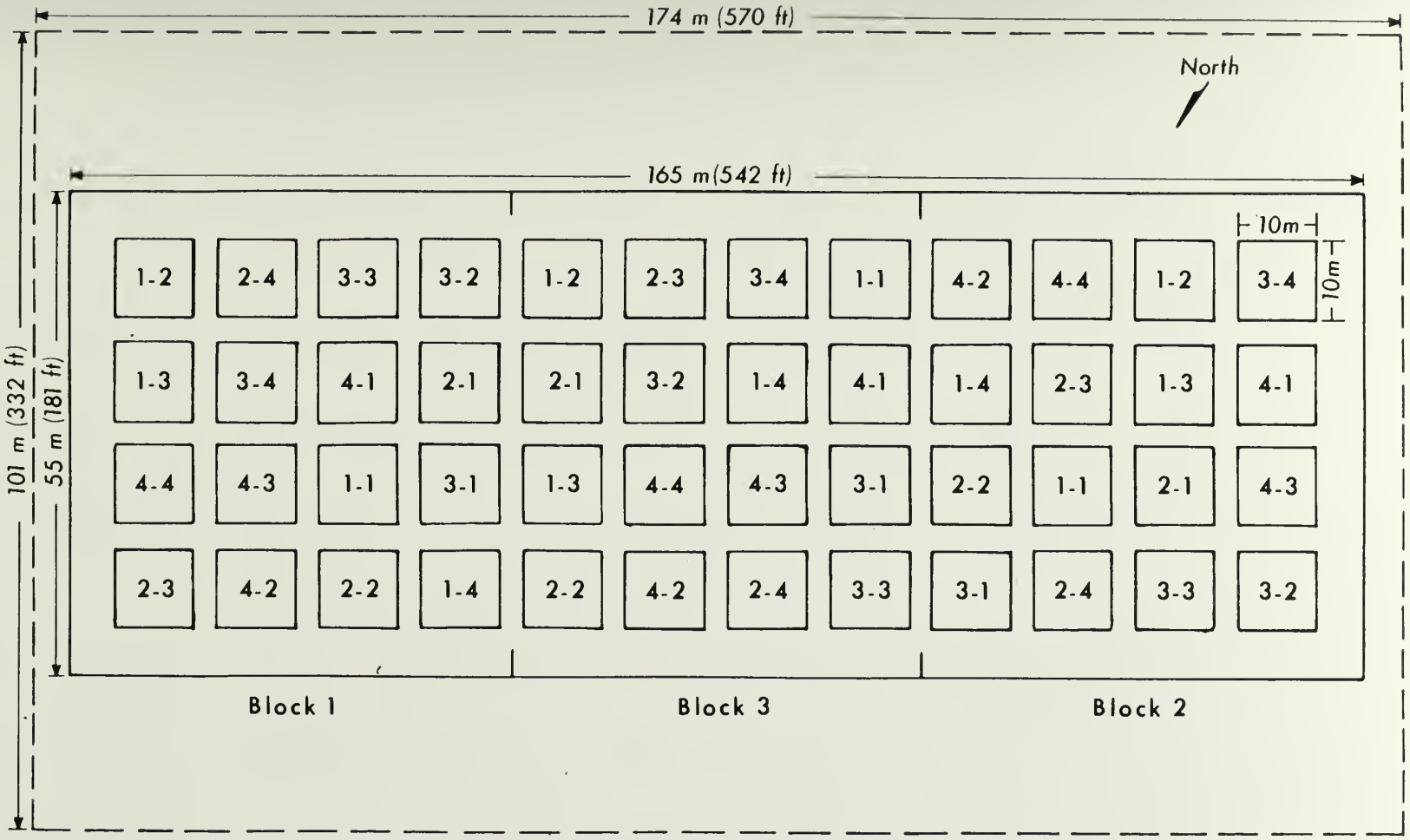
Coverage for all species by treatment combination on R-1 ranged from 30.9 o 51.2 percent, with a mean of 40. Planted grasses accounted for 46 percent of

Table 6-2. Coverage (%) of Planted and Invaded Grasses, Forbs and Shrubs for Experimental Revegetation Plots R-1 and R-2 during 1980, Tract C-a[1/]

Treatment Combination	R-1							R-2						
	Grasses		Forbs		Shrubs		Total Cover	Grasses		Forbs		Shrubs		Total Cover
	Planted	Invaded	Planted	Invaded	Planted	Invaded		Planted	Invaded	Planted	Invaded	Planted	Invaded	
No Mulch No Fertilizer	20.8	0.2	8.4	5.8	5.4	ND	40.6	14.2	0.2	11.8	6.3	7.1	ND	39.6
No Mulch Fertilized at Sowing	11.8	8.2	17.3	5.6	2.2	ND	45.1	13.6	0.6	4.7	9.1	7.8	ND	35.8
No Mulch Fertilized First Season	20.1	2.2	6.7	2.8	3.5	ND	35.3	12.5	0.6	9.3	8.3	7.6	ND	38.3
No Mulch Fertilized Sowing/First	22.2	3.6	9.2	5.6	4.2	ND	44.8	16.3	0.7	4.3	12.9	7.5	0.2	41.9
Hydromulch No Fertilizer	19.6	0.5	8.2	2.8	3.8	ND	34.9	10.8	0.7	7.9	4.5	11.7	ND	35.6
Hydromulch Fertilized at Sowing	17.2	0.9	13.3	4.2	4.6	ND	40.2	13.4	1.0	8.6	5.4	6.8	ND	35.2
Hydromulch Fertilized First Season	22.9	2.2	14.8	1.8	4.2	ND	45.9	18.1	0.8	9.0	5.5	10.2	ND	43.6
Hydromulch Fertilized Sowing/First	13.4	9.4	18.4	7.8	2.2	ND	51.2	16.7	1.4	6.2	5.5	8.2	ND	38.0
Straw Crimped No Fertilizer	17.1	0.2	5.2	10.0	3.4	0.2	36.1	18.6	ND	7.8	6.7	3.7	ND	36.8
Straw Crimped Fertilized at Sowing	14.6	0.2	15.4	6.5	2.7	ND	39.4	14.4	ND	12.8	5.9	3.0	ND	36.1

Table 6-2. (Continued)

Treatment Combination	R-1 Grasses Planted	R-1 Grasses Invaded	R-1 Forbs Planted	R-1 Forbs Invaded	R-1 Shrubs Planted	R-1 Shrubs Invaded	R-1 Total Cover	R-2 Grasses Planted	R-2 Grasses Invaded	R-2 Forbs Planted	R-2 Forbs Invaded	R-2 Shrubs Planted	R-2 Shrubs Invaded	R-2 Total Cover
Straw Crimped Fertilized First Season	12.9	4.7	8.7	13.2	1.2	ND	40.7	17.2	0.5	7.8	10.1	5.5	ND	41.1
Straw Crimped Fertilized Sowing/First	16.7	7.4	4.7	9.1	1.2	ND	39.1	15.4	0.2	8.2	6.8	3.2	ND	33.8
Straw with Netting No Fertilizer	25.7	1.1	1.7	1.2	1.2	ND	30.9	13.4	0.9	7.3	6.5	5.1	ND	33.2
Straw with Netting Fertilized at Sowing	16.7	5.0	10.8	9.2	3.2	ND	44.9	16.7	ND	10.5	6.3	2.9	ND	36.4
Straw with Netting Fertilized First Season	21.4	2.9	7.7	2.9	1.6	ND	36.5	15.8	0.5	8.9	3.5	4.8	ND	33.5
Straw with Netting Fertilized Sowing/First	22.2	0.6	6.5	8.5	2.4	ND	40.2	14.0	1.8	7.2	6.8	4.2	ND	34.0



Seeding Rate 18 kg/ha (16 lbs/acre)

Mulch Treatments:

(First Numeral in Treatment Designation)

1=No Mulch
2=Hydromulch
3=Straw Mulch Followed by Crimping
4=Straw Mulch With Netting

Fertilizer Treatments:

(180 kg/ha, 10-5-5)

(Second Numeral in Treatment Designation)

1=No Fertilizer
2=Fertilizer at Time of Sowing
3=Fertilizer at Beginning of First Full Growing Season
4=Fertilizer at Sowing & Beginning of First Full Growing Season

Figure 6-1. Treatment Configuration for Experimental Revegetation Plot R1, Tract C-a.

total coverage averaged over all treatments. The lowest coverage of planted grasses (11.8 %) was encountered on treatment plots with no mulch and fertilizer at the time of sowing. Plots with straw mulch covered with netting and no fertilizer exhibited the highest grass coverage (25.7%). Wheatgrass (Agropyron) species and Indian ricegrass (Oryzopsis hymenoides) were the prominent grasses encountered on most treatment combinations. These and other planted grasses were dominant on all treatments, but invading species, primarily cheat-grass (Bromus tectorum) and crested wheatgrass (Agropyron cristatum) also were encountered. Coverage of invading grass species ranged from 0.2 to 9.4 percent, with the average for all treatment combinations being 3.1 percent (Table 6-2).

A comparison of graminoid coverage between treatment combinations indicated that there were no significant differences for either interaction or main effects based on 1980 data (Table 6-3). However, when grass coverage on R-1 is compared between 1976, 1977, 1978 and 1980 significant differences are noted for both planted and invaded grass species (Table 6-4). Results of Duncan's multiple range tests indicate that coverage of planted grasses recorded during 1980 is significantly higher than all other years (Table 6-5). Coverage between 1977 and 1978 was not significantly different, however, this two year period exhibited higher coverage than that recorded for 1976. Coverage of invaded grass species was similar during 1976 and 1980 but significantly higher than that for either 1977 or 1978 (Table 6-5). One might expect that coverage of invaders would be highest when there was a large percentage of bare ground and low competition from planted species. The 1976 data illustrate this phenomenon, but it is unclear why the coverage of invading grasses reaches another peak in 1980. It is possible that the clipping of sample plots during 1978 allowed for increased invasion during 1979.

Using a three-way ANOVA to compare grass coverage over four years, it is evident that the differences noted above are a result of main effect differences in mulch and fertilizer treatments (Table 6-6). Because the interaction effect mulch x fertilizer is not significant, it appears that the two main effect parameters are acting independently. Results of Duncan's multiple range tests illustrating the main effect differences are presented on Table 6-7. There are no significant differences in grass coverage for straw

Table 6-3. Results of Three-way ANOVA's Comparing Grass, Forb, and Shrub Coverage of Planted and Invaded Species for Treatment Combinations during 1980 on Experimental Revegetation Plots R-1 and R-2, Tract C-a[1/]

Growth Forms	Source of Variation: Block F	Block PR>F[2/]	Mulch F	Mulch PR>F[2/]	Fertilizer F	Fertilizer PR>F[2/]	Block x Mulch F	Block x Mulch PR>F[2/]	Block x Fertilizer F	Block x Fertilizer PR>F[2/]	Mulch x Fertilizer F	Mulch x Fertilizer PR>F[2/]	Block x Mulch x Fertilizer F	Block x Mulch x Fertilizer PR>F[2/]
R-1														
Grasses Planted	0.40	0.6690	0.82	0.4871	1.27	0.2864	0.26	0.9545	0.31	0.9305	0.36	0.9504	0.26	0.9989
Grasses Invaded	0.04	0.9602	0.22	0.8819	0.81	0.5171	0.82	0.5791	0.87	0.5514	1.10	0.4364	0.56	0.7273
Forbs Planted	0.38	0.6876	1.86	0.1410	3.04*	0.0327	0.60	0.7318	0.75	0.6091	0.96	0.4782	0.76	0.7390
Forbs Invaded	2.44	0.0899	2.05	0.1074	0.54	0.6566	0.86	0.5276	1.09	0.3702	1.08	0.3804	1.40	0.1388
Shrubs Planted	0.35	0.7037	1.59	0.1979	0.67	0.5736	0.37	0.8960	1.65	0.1439	1.06	0.4025	0.50	0.9480
Shrubs Invaded[3/]														
R-2														
Grasses Planted	1.96	0.1445	0.61	0.6128	0.37	0.7742	0.23	0.9673	0.36	0.9023	0.50	0.8730	0.30	0.9977
Grasses Invaded	0.55	0.6136	0.26	0.8514	0.07	0.9722	0.18	0.9660	0.33	0.8907	0.12	0.9812	0.12	0.7465
Forbs Planted	1.55	0.2188	0.94	0.4279	1.37	0.2572	1.03	0.4112	0.51	0.8008	1.16	0.3335	1.20	0.2790
Forbs Invaded	3.54*	0.0309	3.43*	0.0180	0.98	0.4034	1.22	0.2990	0.75	0.6071	1.66	0.1018	0.87	0.6119
Shrubs Planted	0.34	0.7120	2.05	0.1133	0.53	0.6675	0.76	0.6001	0.38	0.8893	0.11	0.9992	0.77	0.7250
Shrubs Invaded[3/]														

* Significant at $\alpha = 0.05$

[1/] Complete analyses are presented in Appendix 6-2.2

[2/] PR>F represents the significant probability (α) associated with F

[3/] Invaded shrub species were not encountered in numbers sufficient to produce F values for the ANOVA

Table 6-4. Results of One-way ANOVA Comparing Arcsine Transformed Coverage Estimates for Grasses, Forbs and Shrubs between 1976, 1977, 1978 and 1980 for Experimental Revegetation Plots R-1 and R-2, Tract C-a[1/]

Growth Form	Source of Variation: Year	
	F	PR>F[2/]
R-1		
Grasses Planted	57.62*	0.0001
Grasses Invaded	7.64*	0.0001
Forbs Planted	58.99*	0.0001
Forbs Invaded	23.99*	0.0001
Shrubs Planted	12.45*	0.0001
Shrubs Invaded[3/]		
R-2		
Grasses Planted	48.23*	0.0001
Grasses Invaded	21.65*	0.0001
Forbs Planted	74.37*	0.0001
Forbs Invaded	24.69*	0.0001
Shrubs Planted	50.32*	0.0001
Shrubs Invaded[3/]		

* Significant at $\alpha = 0.05$

1/ Complete analyses are presented in Appendix 6-2.2

2/ Represents the significance probability (α) associated with F

3/ Invaded shrub species were not encountered in numbers sufficient to produce F values for the ANOVA

Table 6-5. Results of Duncan's Multiple Range Tests for Significant Differences in Coverage of Planted (first listing) and Invaded (second listing) Grass Species between 1976, 1977, 1978 and 1980 on Plot R-1, Tract C-a

GENERAL LINEAR MODELS PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE ASPC

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=815 MS=.0166979

GROUPING	MEAN	N	YEAR
A	0.210492	175	80
B	0.118019	180	78
B			
B	0.115487	206	77
C	0.044294	258	76

ALPHA LEVEL=.05 DF=126 MS=.0189784

GROUPING	MEAN	N	YEAR
A	0.137652	45	80
A			
A	0.136954	36	76
B	0.018618	36	78
B			
B	0.016155	13	77

Table 6-6. Results of Three-way ANOVA Comparing Grass, Forb, and Shrub Coverage of Planted and Invaded Species for Treatment Combinations between 1976, 1977, 1978 and 1980 for Experimental Revegetation Plots R-1 and R-2, Tract C-a[1/]

Growth Forms	Source of Variation: Block F	Block PR>F[2/]	Mulch F	Mulch PR<[2/]	Fertilizer F	Fertilizer PR>F[2/]	Block x Mulch F	Block x Mulch PR>F[2/]	Block x Fertilizer F	Block x Fertilizer PR>F[2/]	Mulch x Fertilizer F	Mulch x Fertilizer PR>F[2/]	Block x Mulch x Fertilizer F	Block x Mulch x Fertilizer PR>F[2/]
R-1														
Grasses Planted	0.64	0.5290	2.66*	0.0463	5.43*	0.0012	0.12	0.9944	0.95	0.4613	1.32	0.2194	0.72	0.7899
Grasses Invaded	0.00	0.9972	0.81	0.4961	1.78	0.1550	1.72	0.1249	0.69	0.6555	1.37	0.2148	0.61	0.8461
Forbs Planted	0.53	0.5916	5.65*	0.0009	3.40*	0.0175	0.64	0.6949	0.48	0.8230	1.13	0.3378	0.65	0.8628
Forbs Invaded	1.04	0.3545	2.71*	0.0434	1.54	0.2021	0.54	0.7783	0.99	0.4320	0.62	0.7785	0.78	0.7301
Shrubs Planted	1.22	0.2963	26.99*	0.0001	3.22*	0.0222	1.36	0.2277	4.46*	0.0002	0.61	0.7909	1.61	0.0535
Shrubs Invaded[3/]														
R-2														
Grasses Planted	1.03	0.3557	0.40	0.7557	3.71*	0.0115	0.34	0.9154	0.63	0.7070	0.66	0.7495	0.45	0.9752
Grasses Invaded	0.40	0.6731	5.05*	0.0033	1.46	0.2321	1.34	0.2504	0.26	0.9529	1.24	0.2857	0.76	0.7308
Forbs Planted	0.65	0.5222	2.45	0.0608	1.71	0.1622	0.66	0.6839	0.51	0.7996	0.55	0.8383	0.62	0.8881
Forbs Invaded	1.09	0.3375	3.05*	0.0277	1.78	0.1469	0.72	0.6301	0.66	0.6860	0.63	0.7744	0.70	0.8146
Shrubs Planted	1.16	0.3132	12.12*	0.0001	0.17	0.9137	1.77	0.1038	0.77	0.5946	0.49	0.8839	0.52	0.9480
Shrubs Invaded[3/]														

* Significant at $\alpha = 0.05$

[1/] Complete analyses are presented in Appendix 6-2.2

[2/] PR>F represents the significant probability (α) associated with F

[3/] Invaded shrub species were not encountered in numbers sufficient to produce F values for the ANOVA

Table 6-7. Results of Duncan's Multiple Range Tests for Significant Main Effect Differences, Mulch and Fertilizer, in Coverage of Planted Grasses between 1976, 1977, 1978 and 1980 on Plot R-1, Tract C-a [1/]

GENERAL LINEAR MODELS PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE ASPC

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=771 MS=.0199256

GROUPING		MEAN	N	MULCH
	A	0.129510	207	4
	A			
B	A	0.117677	207	2
B	A			
B	A	0.116772	200	1
B				
B		0.091588	205	3

ALPHA LEVEL=.05 DF=771 MS=.0199256

GROUPING		MEAN	N	FERTILIZ
	A	0.140476	215	1
	A			
B	A	0.117934	206	3
B				
B	C	0.110867	201	4
	C			
	C	0.083840	197	2

[1/] Mulch and fertilizer treatments are illustrated on Figure 6-1.

mulch with netting, hydromulch, or no mulch treatments. Similarly, the grouping of hydromulch, no mulch, and straw mulch followed by crimping were not significantly different. The only mulch treatments which were significantly different are the two straw mulches. Three groupings are evident for fertilizer treatments based on four years of data. Although each of the four fertilizer treatments is similar to one other treatment, the only treatments not interconnected were no fertilizer and fertilizer at the time of sowing. The plots without fertilizer had significantly higher grass coverage than those fertilized at the time of sowing.

Coverage of planted forb species averaged 9.8 percent, with a range of 1.7 to 18.4 percent for all treatment combinations. Forbs accounted for 24 percent of all coverage on R-1 (Table 6-2). Highest coverage of planted forbs was encountered with hydromulch and fertilization at the time of sowing as well as at the beginning of the first full year of growth. The lowest forb coverage was recorded on plots with straw mulch covered by netting and no fertilization. Of the five species of forbs planted, Lewis flax (Linum lewisii), cicer milkvetch (Astragalus cicer var. Lutana), and yellow sweetclover (Melilotus officinalis var. Madrid) account for the majority of forb coverage. Invaded forbs which are most prevalent include Russian thistle (Salsola kali), twin pod (Physaria floribunda) and Douglas chaenactis (Chaenactis douglasii). The combined coverage of all invaded forb species for all treatment combinations ranges from 1.2 to 13.2 percent, with the average being 6.1 percent. It should be noted that coverage of invaded forbs is approximately twice that for invaded grasses.

Results of a three-way ANOVA comparing forb coverage over all treatment combinations for 1980 indicate that the only significant differences were for planted forbs, as based on fertilizer treatments (Table 6-3). Two groups of fertilizer treatment combinations resulted from a Duncan's multiple range test on the significant main effect difference (Table 6-8). There is no significant difference between most fertilizer treatments, but data indicate that coverage of planted forbs is significantly higher on plots fertilized at the time of sowing than where no fertilizer was used.

Table 6-8. Results of a Duncan's Multiple Range Test on the Significant Main Effect Difference, Fertilizer, in Coverage of Planted Forbs for 1980 on Plot R-1, Tract C-a [1/]

GENERAL LINEAR MODELS PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE ASPC

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=90 MS=.0262977

GROUPING		MEAN	N	FERTILIZ
	A	0.193259	37	2
	A			
B	A	0.153425	31	4
B	A			
B	A	0.125420	37	3
B				
B		0.086140	33	1

[1/] Fertilizer treatments are illustrated on Figure 6-1.

Significant differences also were noted for coverage of both planted and invaded forbs between four sample years (Table 6-4). Table 6-9 illustrates the results of Duncan's multiple range tests on these differences. Coverage of planted forbs is significantly higher during 1980 than for either 1976, 1977 or 1978. It is interesting to note that concomitant with these increases, coverage of invaded forbs is significantly lower than for any of the previous sampling periods. Data indicate that invading forbs increased significantly from 1976 through 1978. Clipping of standing crop for biomass determinations in 1978 may be the cause of decreased coverage of invading forbs noted in 1980. If this is the case, it is unclear why coverage of planted forb species did not exhibit a similar response.

Based on four sampling periods, results of three-way ANOVA indicate that the source of variation in coverage of planted forb species is a function of mulch and fertilizer (Table 6-6). However, these treatments show no significant interactive effect so that one can assume that they influence forb coverage independent of one another. Significantly higher forb coverage was evident on plots with no mulch and/or hydromulch as compared to either of the straw mulch treatments (Table 6-10). Treatment combinations having either no fertilizer or fertilizer at the beginning of the first year of growth exhibited significantly lower forb coverage than plots fertilized only at the time of seeding.

Shrub coverage for all treatment combinations on R-1 averaged 2.9 percent, with a range from 1.2 to 5.4 percent. Highest coverage was recorded for the no mulch/no fertilizer treatment. Three treatment combinations had equally low coverage of planted shrubs (Table 6-2). The most prevalent shrub species encountered throughout all of the R-1 treatment combinations were rabbitbrush (Chrysothamnus nauseosus and C. viscidiflorus) species and winterfat (Ceratoides lanata). Of the remaining six planted shrub species, only big sagebrush (Artemisia tridentata) and bitterbrush (Purshia tridentata) were encountered with regularity, and their contributions to overall shrub coverage were small. An unidentified shrub species was encountered within one sample but no other invading shrubs were encountered. One suffruticose invading species, (Gutierrezia sarothrae) was encountered but was included in the category of invading forbs rather than shrubs.

Table 6-9. Results of Duncan's Multiple Range Tests for Significant Differences in Coverage of Planted (first listing) and Invaded (second listing) Forb Species between 1976, 1977, 1978 and 1980 on Plot R-1, Tract C-a

GENERAL LINEAR MODELS PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE ASPC

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=630 MS=.0067965

GROUPING	MEAN	N	YEAR
A	0.140507	138	80
B	0.045840	170	77
B			
C B	0.035087	197	76
C			
C	0.025609	129	78

ALPHA LEVEL=.05 DF=677 MS=0.124223

GROUPING	MEAN	N	YEAR
A	0.373626	105	78
B	0.253443	177	77
C	0.126761	176	76
D	0.053318	223	80

Table 6-10. Results of Duncan's Multiple Range Tests on Significant Main Effect Differences, Mulch (first listing) and Fertilizer (second listing), in Coverage of Planted Forbs between 1976, 1977, 1978 and 1980 on Plot R-1, Tract C-a [1/]

GENERAL LINEAR MODELS PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE ASPC

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=586 MS=.0085323

GROUPING	MEAN	N	MULCH
A	0.078515	167	2
A			
A	0.068246	146	1
B	0.047161	160	3
B			
B	0.042091	161	4

ALPHA LEVEL=.05 DF=586 MS=.0085323

GROUPING	MEAN	N	FERTILIZ
A	0.077247	153	2
A			
B A	0.060492	146	4
B			
B	0.052719	164	3
B			
B	0.047380	171	1

[1/] Mulch and fertilizer treatments are illustrated on Figure 6-1.

Although no significant differences were noted for coverage of planted shrubs among the various treatment combinations for 1980 (Table 6-3), one-way ANOVA indicate that there were differences between years (Table 6-4). Coverage of shrubs was significantly lower after one year's growth than that exhibited in subsequent years (Table 6-11). Analyses show that, although coverage increased slightly, there were no significant changes in shrub coverage from 1977 through 1980. It seems likely that clipping of the standing crop during 1978 has inhibited growth more for shrub species than for either grasses or for forbs, both of which exhibited significantly greater coverage for 1980 than for previous years.

Significant differences in shrub coverage between years seems to be related to mulch and/or fertilizer treatments (Table 6-6). Results of Duncan's multiple range tests on these significant main effects are presented on Table 6-12. Shrub coverage seems to be adversely influenced by both straw mulch treatments. Coverage for hydromulched plots was significantly higher than that for straw mulching, but the no mulch treatment had significantly higher coverage than any of the mulch amendments. Planted shrubs exhibited significantly higher coverage on plots fertilized at the time of sowing than on plots with any of the other fertilizer applications. It appears that the significant interaction term, block x fertilizer, results from the fertilizer treatment rather than differences in shrub coverage between blocks.

b. Experimental Revegetation Plot R-2 - Estimates of coverage for plot R-2 were made between August 7-11, 1980. The configuration of R-2 treatment combinations is illustrated on Figure 6-2.

Coverage for all species by treatment combination ranged from 33.2 to 43.6 percent, with a mean of 37.1. Planted grasses accounted for 41 percent of total coverage averaged over all treatment combinations. The lowest grass coverage (10.8%) was encountered on the hydromulched plots without fertilizer. Plots with crimped straw mulch and no fertilizer exhibited the highest grass coverage (18.6%) (Table 6-2). Wheatgrass and Indian ricegrass species were the dominant grasses encountered on most treatment combinations, while green needlegrass (Stipa viridula) was a common subordinate species. Coverage of invading

Table 6-11. Results of a Duncan's Multiple Range Tests for the Significant Main Effect Difference in Coverage of Planted Shrub Species between 1976, 1977, 1978 and 1980 on Plot R-1, Tract C-a

GENERAL LINEAR MODELS PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE ASPC

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=648 MS=.0011099

GROUPING	MEAN	N	YEAR
A	0.044430	128	80
A			
A	0.039403	180	78
A			
A	0.038414	166	77
B	0.023154	178	76

Table 6-12. Results of Duncan's Multiple Range Tests for Significant Main Effect Difference, Mulch (first listing) and Fertilizers (second listing), in Coverage of Planted Shrub Species between 1976, 1977, 1978 and 1980 on Plot R-1, Tract C-a [1/]

GENERAL LINEAR MODELS PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE ASPC

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

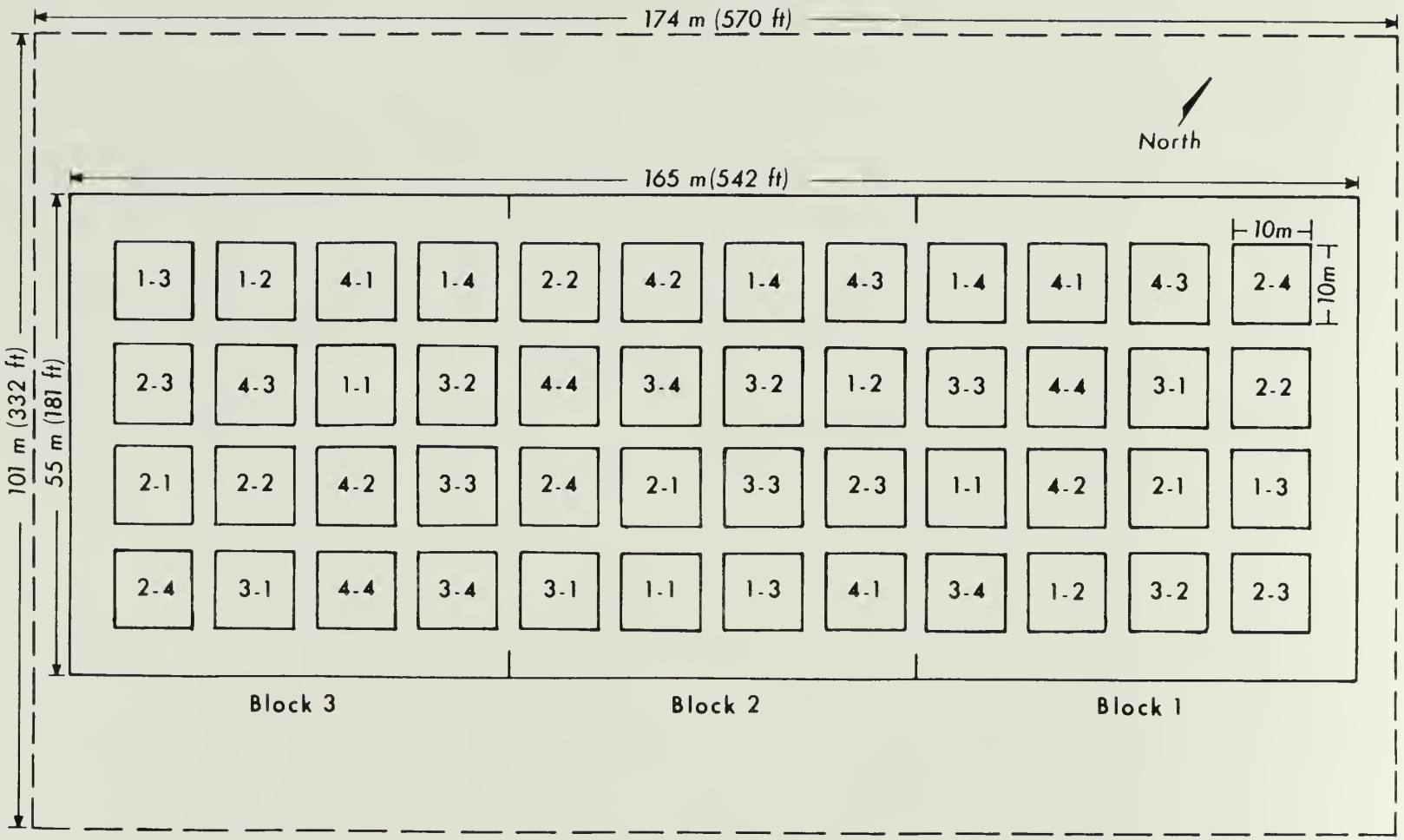
ALPHA LEVEL=.05 DF=604 MS=9.9E-04

GROUPING	MEAN	N	MULCH
A	0.051262	154	1
B	0.041897	173	2
C	0.025212	156	4
C			
C	0.024865	169	3

ALPHA LEVEL=.05 DF=604 MS=9.9E-04

GROUPING	MEAN	N	FERTILIZ
A	0.041276	149	2
A			
B A	0.037463	194	1
B			
B	0.033322	149	4
B			
B	0.030593	160	3

[1/] Mulch and fertilizer treatments are illustrated on Figure 6-1



Seeding Rate 18 kg/ha (16 lbs/acre)

Mulch Treatments:
(First Numeral in Treatment Designation)

1=No Mulch
2=Hydromulch
3=Straw Mulch Followed by Crimping
4=Straw Mulch With Netting

Fertilizer Treatments:
(180 kg/ha, 10-5-5)
(Second Numeral in Treatment Designation)

1=No Fertilizer
2=Fertilizer at Time of Sowing
3=Fertilizer at Beginning of First Full Growing Season
4=Fertilizer at Sowing & Beginning of First Full Growing Season

Figure 6-2. Treatment Configuration for Experimental Revegetation Plot R2, Tract C-a.

grasses ranged from 0.0 to 1.8 percent, with the average being 0.62 percent. Cheat-grass and/or crested wheatgrass were encountered on 13 of 16 treatment combinations (Table 6-2).

A comparison of grass coverage between treatments for 1980 data indicated no significant differences for either main or interaction effects (Table 6-3). However, when 1976, 1977, 1978 and 1980 data were compared, significant differences in coverage of planted and invaded grasses were noted (Table 6-4). The results of Duncan's multiple range tests illustrate these differences (Table 6-13). Coverage of planted grasses was significantly higher in 1980 than during any of the previous years. Coverage between 1977 and 1978 was not significantly different, but was significantly higher than for 1976. It is interesting to note that grass species seem to have recovered quite well from the clipping conducted during 1978. These data indicate that heavy grazing, as simulated by the 1978 clipping, may not be detrimental to grasses within revegetated areas, provided that the sites receive a rest rotation between grazing.

Coverage attributed to invading grasses was not significantly different for 1980, 1978 and 1977, but these years exhibited significantly lower coverage than for 1976. High coverage of invaders would be expected for 1976 due to the large amount of bare ground and low competition from planted species during the first year after sowing. The cause of increased invasion of grasses during the period between 1978 and 1980 may be related to the clipping conducted in 1978. Decreased coverage and competition after clipping may have afforded an amenable environment for the invaders. If this is the case, one would expect coverage of invaded grasses to decrease in the next few years as they are out competed by the planted species.

Using a three-way ANOVA to compare grass coverage over four years, it appears that the differences noted above are due in part to significant main effect differences in mulch and fertilizer treatments (Table 6-6). Because interaction effects do not show significant differences, one can assume that there is no combined influence between either block, mulch or fertilizer treatments. Results of Duncan's multiple range tests on the significant main effect differences are noted on Table 6-14. Planted grasses exhibited significantly higher coverage on plots without fertilizer than on those fertilized at the time of

Table 6-13. Results of Duncan's Multiple Range Tests for Significant Differences in Coverage of Planted (first listing) and Invaded (second listing) Grass Species between 1976, 1977, 1978 and 1980 on Plot R-2, Tract C-a

GENERAL LINEAR MODELS PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE ASPC

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=824 MS=.0106761

GROUPING	MEAN	N	YEAR
A	0.159301	184	80
B	0.118019	180	78
B			
B	0.115487	206	77
C	0.044294	258	76

ALPHA LEVEL=.05 DF=113 MS=.0048638

GROUPING	MEAN	N	YEAR
A	0.136954	36	76
B	0.038416	31	80
B			
B	0.018655	37	78
B			
B	0.016155	13	77

Table 6-14. Results of Duncan's Multiple Range Tests for Significant Main Effect Differences in Coverage of Planted Grasses (fertilizer) and Invaded Grasses (mulch) between 1976, 1977, 1978 and 1980 on Plot R-2, Tract C-a[1/]

GENERAL LINEAR MODELS PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE ASPC

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=897 MS=.0122431

GROUPING	MEAN	N	FERTILIZ
A	0.115454	245	1
A			
B A	0.099010	240	3
B A			
B A	0.095385	241	4
B			
B	0.081088	219	2

ALPHA LEVEL=.05 DF=70 MS=.0069784

GROUPING	MEAN	N	MULCH
A	0.096473	32	3
A			
B A	0.070583	41	4
B			
B C	0.027636	21	2
C			
C	0.020006	23	1

[1/] Fertilizer and mulch treatments are illustrated on Figure 6-2

sowing. Groupings of invaded grasses based on mulch treatments were more complex. The straw mulch treatments were similar to each other, but supported significantly higher coverage of invading grasses than either the hydromulch or no mulch treatments. Straw mulch with netting had invaded grass coverage similar to hydromulch but higher than the no mulch treatment. Higher coverage of invading grasses on straw mulch treatments might be due to the introduction of grass seed with the straw. Because differences in grass coverage between treatments were not significant based only on 1980 data, one can assume that the beneficial influences that mulch treatments may have afforded during early plant establishment are lost with time.

Coverage of planted forbs averaged over all treatment combinations was 8.3 percent, with a range from 4.3 to 12.8 percent (Table 6-2). Planted forb species account for approximately 22 percent of all coverage recorded. The lowest coverage of planted forbs was recorded for plots with no mulch treatment, and fertilizer both at sowing and at the beginning of the first growing season. Crimped straw mulch with fertilizer at the time of sowing resulted in the highest coverage. Of the six planted species, cicer milkvetch, Lewis flax, and yellow sweetclover accounted for nearly all of the forb coverage. In addition, invading forb species contributed coverages ranging from 3.5 to 12.9 percent, the average for all treatment combinations being 6.9 percent. Prominent invading forb species included Russian thistle, Douglas chaenactis, twin pod, and Cryptantha sericea.

Analysis of 1980 data indicates that significant differences in cover exist only for invaded forb species, based on the block and mulch main effects of a three-way ANOVA (Table 6-3). Results of Duncan's multiple range tests illustrate these differences (Table 6-15). Coverage for most mulch types is not significantly different, however the no mulch treatment did have significantly higher coverage of invading forbs than the hydromulched plots. The invading forb category on R-2 was the only instance in which significant differences were noted between blocks. Such differences are not expected in a truly random design and it is unclear why block three exhibited significantly higher coverage than block one.

Table 6-15. Results of Duncan's Multiple Range Tests for Significant Main Effect Differences, Mulch (first listing) and Block (second listing), in Coverage of Invaded Forb Species for 1980 on Plot R-2, Tract C-a[1/]

GENERAL LINEAR MODELS PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE ASPC

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=187 MS=.0049739

GROUPING	MEAN	N	MULCH
A	0.078102	57	1
A			
B A	0.058882	58	3
B A			
B A	0.050793	55	4
B			
B	0.038662	65	2

ALPHA LEVEL=.05 DF=187 MS=.0049739

GROUPING	MEAN	N	BLOCK
A	0.070322	78	3
A			
B A	0.057915	75	2
B			
B	0.040790	82	1

[1/] Mulch treatments and block configurations are illustrated on Figure 6-2

When data for all years are considered, significant differences are indicated for both planted and invaded forbs (Table 6-4). Duncan's multiple range test results indicate that coverage of planted forbs during 1980 was significantly higher than for the remaining three years (Table 6-16). These results are similar to those evidenced for grass species on plot R-2 and indicate that planted forbs, as well as grasses, have responded quite well to the clipping conducted during the 1978 sample period. Invading forbs exhibited significantly lower coverage during 1980 than for 1976, 1977, or 1978. It is uncertain why invading forb species appear to react conversely to invading grasses, but coverage of both groups seems to be related to mulch treatments. Table 6-6 presents ANOVA results which indicate that, like invaded grasses, coverage of invaded forbs is significantly different for the main effect mulch when four years of data are compared. In this instance, coverage on the no mulch treatment is similar to the two straw mulches but significantly higher than recorded for the hydromulch treatment (Table 6-17).

Shrub coverage (6.2%) on plot R-2 represents nearly 17 percent of mean coverage over all treatment combinations (Table 6-2). Lowest shrub cover (2.9%) was noted for plots with straw mulch and netting when fertilization occurred at the time of seeding. Highest coverage (11.7%) was experienced on plots which were hydromulched but had no fertilization. Rabbitbrush species and winterfat were the dominant shrub species. Of the remaining five planted shrubs bitterbursh was the only species encountered with regularity. Only one unidentified invading shrub was encountered. One suffruticose species, Gutierrezia sarothrae, was a fairly common invader but, for purposes of this report, it was included with the invading forb species.

Based on 1980 data, no significant main or interaction effects were noted for shrub species (Table 6-3). For all four years, however, differences in coverage of planted shrubs were evident (Table 6-4). Duncan's multiple range test results indicate that coverage in 1980 was significantly higher than for all other years (Table 6-18). The 1976 coverage was significantly lower than for the remaining periods. Low values for 1976 are reasonable since this was the first full year of growth. High coverage during 1980 seems unusual in that plants were clipped for biomass determinations in 1978. One might expect

Table 6-16. Results of Duncan's Multiple Range Tests for Significant Differences in Coverage of Planted (first listing) and Invaded (second listing) Forb Species between 1976, 1977, 1978 and 1980 on Plot R-2, Tract C-a

GENERAL LINEAR MODELS PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE ASPC

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=616 MS=.0040267

GROUPING	MEAN	N	YEAR
A	0.129842	124	80
B	0.045840	170	77
B			
C B	0.035087	197	76
C			
C	0.025609	129	78

ALPHA LEVEL=.05 DF=689 MS=0.120976

GROUPING	MEAN	N	YEAR
A	0.373626	105	78
B	0.253443	177	77
C	0.126761	176	76
D	0.056058	235	80

Table 6-17. Results of a Duncan's Multiple Range Test on the Significant Main Effect Difference, Mulch, in the Coverage of Invaded Forb Species between 1976, 1977, 1978 and 1980 on Plot R-2, Tract C-a[1/]

GENERAL LINEAR MODELS PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE ASPC

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=645 MS=0.134141

GROUPING	MEAN	N	MULCH
A	0.220624	138	1
A			
A	0.197677	193	3
A			
B A	0.174592	182	4
B			
B	0.106667	180	2

[1/] Mulch treatments are illustrated on Figure 6-2

Table 6-18. Results of a Duncan's Multiple Range Test for Significant Differences in Coverage of Planted Shrub Species between 1976, 1977, 1978 and 1980 on Plot R-2, Tract C-a

GENERAL LINEAR MODELS PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE ASPC

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=634 MS=0.003441

GROUPING	MEAN	N	YEAR
A	0.105924	114	80
B	0.039403	180	78
B			
B	0.038414	166	77
C	0.023154	178	76

that 1980 coverage would be lower due to the lower growth rate associated with shrub species. This does not appear to be the case on plot R-2.

Analysis of coverage over four years, based on various treatment combinations, indicates that the significant differences present are due in part to variations in mulch treatments (Table 6-6). Higher shrub coverage was noted on hydromulch and no mulch treatments than on either of the straw mulched combinations (Table 6-19). A similar phenomenon was noted for R-1; however, in that instance fertilizer treatments also influenced shrub coverage (Table 6-12).

c. Precipitation at Plots R-1 and R-2 - Rainfall recorded at four locations on the two plots ranged from 7.61 to 7.95 inches for the period April through October 1980 (Table 6-20). The lowest precipitation was noted during the month of June when only 0.03 inches fell on the revegetation plots. Similar data were reported for 1979 when no measureable precipitation was recorded at RBOSC Meteorological Site 2 from June 6 through July 16, 1979. The highest monthly precipitation during the growing period occurred during August when precipitation ranged from 2.3 to 2.58 inches. This August rainfall appears to be unusually high for the Tract C-a area, and represents a 55 percent increase over the .89 inches reported for August 1979 (RBOSC 1980). Based on data from all three experimental revegetation plots, rainfall experienced during the 1980 growing season is 24 percent greater than for the same period during 1979.

B. Experimental Revegetation on a Simulated Processed Shale Disposal Site

1. Objectives

During RBOSC's demonstration of surface retorting technology and subsequent commercial operations, processed shale will be produced as a by-product of surface retorting. This material will require surface disposal because all of the processed shale cannot be returned as a slurry to in-situ retorts. RBOSC initiated revegetation experiments in 1976 to determine a feasible method of reestablishing a productive, self-sustaining range and/or wildlife habitat on processed shale disposal sites.

Table 6-19. Results of a Duncan's Multiple Range Test on the Significant Main Effect Difference, Mulch, in Coverage of Planted Shrub Species between 1976, 1977, 1978 and 1980 on Plot R-2, Tract C-a[1/]

GENERAL LINEAR MODELS PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE ASPC

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=592 MS=.0041051

GROUPING	MEAN	N	MULCH
A	0.062237	160	2
A			
A	0.061962	157	1
B	0.032161	155	4
B			
B	0.030747	168	3

[1/] Mulch treatments are illustrated on Figure 6-2

Table 6-20. Rainfall (inches) Recorded at the RBOSC Experimental Revegetation Sites (R-1, R-2, R-3) from April through October 1980

Month	R-1		R-2		R-3		Average
	Upper	Lower	Upper	Lower	Upper	Lower	
April	1.02	1.0[1/]	1.04	1.09	1.12	1.15	1.07
May	1.61	1.68	1.62	1.72	1.72	1.62	1.66
June	0.03	0.03	0.03	0.03	0.03	0.03	0.03
July	1.0	1.01	0.86	0.91	1.06	1.05	0.98
August	2.45	2.30	2.58	2.54	2.84	2.61	2.55
September	0.62	0.62	0.65	0.68	0.69	0.64	0.65
October[2/]	0.97	0.97	0.96	0.98	0.96	1.02	0.98
TOTAL	7.70	7.61	7.74	7.95	8.42	8.12	7.92

[1/] Some loss may have occurred due to a broken inner gauge

[2/] Approximately 5 inches of snow fell during this period, consequently precipitation determinations may not be accurate

2. Methods

Revegetation plot R-3 was established September 29 - November 8, 1976, and is located near the southeastern corner of Tract C-a (T2S, R99W, Section 10). The plot is situated in an area with a southeast aspect and a slope of approximately 20 percent.

The plot was designed to simulate an artificial soil profile for use in overburden/processed shale disposal piles. This profile consists of 0.9 m of segregated sized overburden-like material, 0.3 m of subsoil, and 0.15 m of topsoil. The overburden-like material (0.9m) is expected to inhibit capillary migration of soluble, potentially toxic components of the processed shale into the surface plant growth medium. The plot configuration at R-3 is designed to test the effectiveness of this reconstructed soil profile, as well as seeding rates and mulch treatments (Figure 6-3). Plots underlain by processed shale are considered treatment plots while those without processed shale are controls.

Soil samples were collected from three depths (0, 1-25, and 26-50 cm) within 36 holes, one centered above each of 36 plots, on R-3. Soil samples were composited by depth for each row in both the treatment and control areas so that the 108 individual samples collected resulted in 36 samples for chemical analysis. Sampling was accomplished using a Soilmoisture Equipment Corp. soil sampling tube.

Additional information on experimental revegetation plot R-3 is available in MDP Monitoring Report 5 (RBOSC 1980) and in Revegetation Annual Reports (RBOSC 1977, 1978, 1979a).

3. Results and Discussion

a. Cover Data - Coverage of grasses, forbs and shrubs on R-3 was estimated between August 5-6, 1980. These data are summarized on Table 6-21 and are presented in their entirety in Appendix 6-2.3.

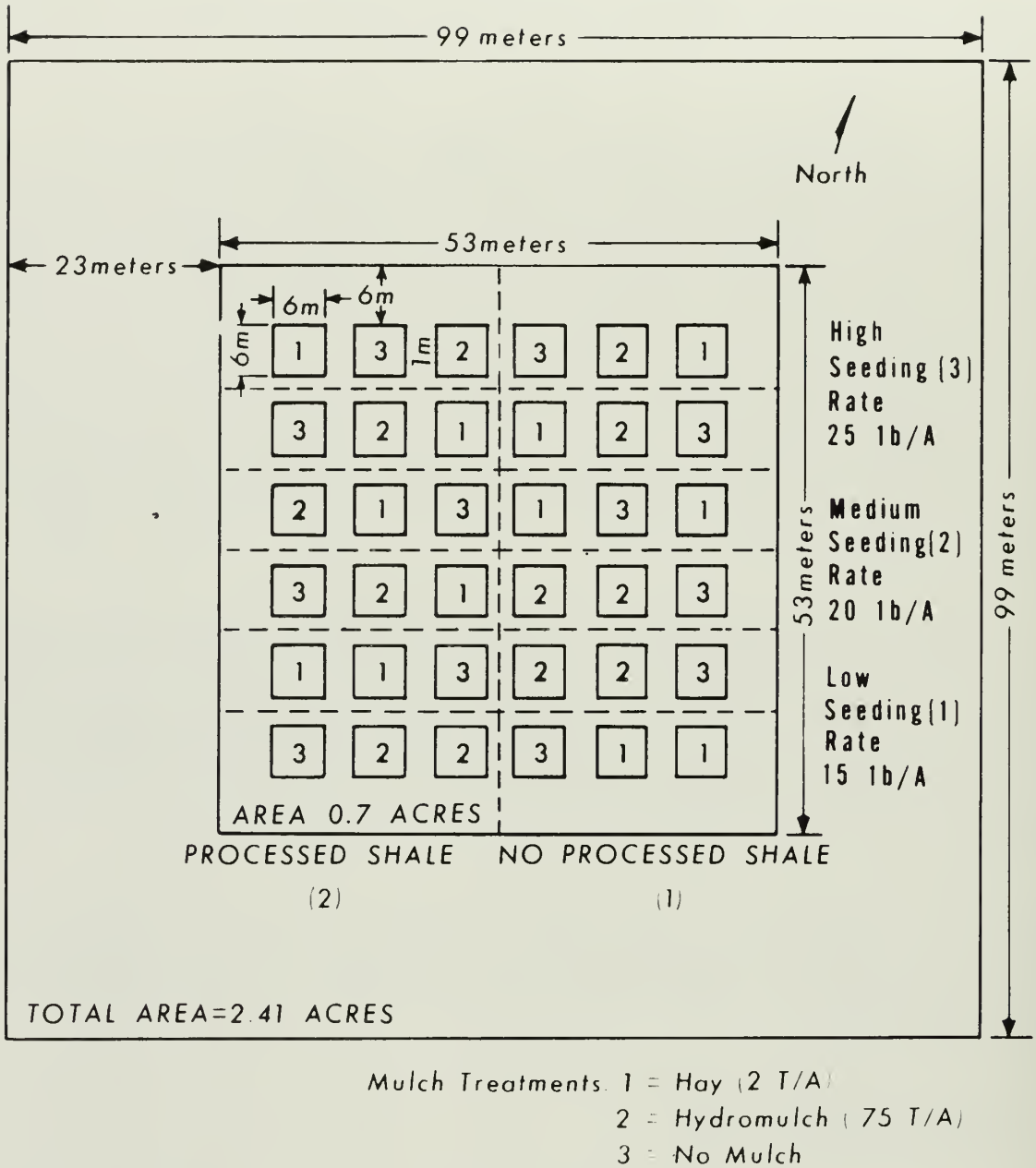


Figure 6-3. Generalized Plot Configuration for Experimental Revegetation Plot R3 on Oil Shale Tract C-a, Rio Blanco County, Colorado (Initiated in 1976).

Coverage on the control portions of R-3 (not underlain by processed shale) ranged from 33.9 to 47.9 percent for all species, with an average of 39.5 percent. Highest coverage was recorded on the hay mulch/low seeding treatment combination while the lowest coverage was found on the no mulch/medium seeding treatment (Table 6-21). Mean coverage on the treatment portion (underlain by processed shale) was 33.9 percent, with a range from 25.7 to 43.8 percent coverage. The hydromulch/low seeding treatment combination had the lowest coverage while the hay mulch/medium seeding plots had the highest coverage. Results of a one-way ANOVA comparing 1980 coverage of all species between the treatment (processed shale) and control (no processed shale) portions of R-3 indicated that there were no significant differences in coverage (Appendix 6-2.4).

When coverage of planted grasses (lumped for all treatment combinations) is compared between the four years of study, significant differences are noted (Table 6-22). Coverage for grasses during 1980 was not significantly different from that recorded for 1977 but was significantly lower than either 1979 or 1978 (Table 6-23). Low coverage during 1980 may be a result of clipping, which was conducted during 1979 in order to make biomass determinations. Although coverage estimates were not made on plots R-1 and R-2 the first year following clipping, data taken two years subsequent to clipping indicate that grass coverage can be expected to increase substantially the second year after clipping.

Coverage of planted grasses during 1980 on the control plots ranged from 14.0 to 32.6 percent, with an average of 25.5. Mean coverage on the treatment plots was slightly lower (24.1%), but the range was almost identical (14.5 to 32.5%). Wheatgrass (Agropyron spp.) species and Indian ricegrass (Oryzopsis hymenoides) were the dominant planted grasses on both the treatment and control plots. Cheat-grass (Bromus tectorum) and crested wheatgrass (Agropyron cristatum) were the most common invading species; however, invading grasses accounted for an average of only 3.8 percent cover on the control and 2.9 percent on the treatment plots (Table 6-21). Based on 1980 data lumped by growth form, there were no significant differences in coverage of either planted or invaded grasses between the treatment and control plots (Table 6-24). Significant differences in coverage of grasses were noted for the main effect of seeding rate. Results

Table 6-21. Coverage (%) of Planted and Invaded Grasses, Forbs and Shrubs for Experimental Revegetation Plot R-3 During 1980, Tract C-a

Mulching & Seeding Treatments[1/]	Control (No Processed Shale)							Treatment (Processed Shale)						
	Grasses		Forbs		Shrubs		Total Cover	Grasses		Forbs		Shrubs		Total Cover
	Planted	Invaded	Planted	Invaded	Planted	Invaded		Planted	Invaded	Planted	Invaded	Planted	Invaded	
No Mulch Low Seeding	26.9	6.2	3.4	0.4	2.0	0.4	39.3	14.5	9.8	1.4	0.6	1.5	ND	27.8
No Mulch Medium Seeding	23.3	0.6	6.2	0.4	2.6	0.8	33.9	25.5	ND	4.8	0.2	3.2	ND	33.7
No Mulch High Seeding	27.4	1.0	1.8	0.3	4.2	ND	34.7	27.6	0.2	1.2	ND	4.3	ND	33.3
Hydromulch Low Seeding	14.0	9.8	12.6	1.0	0.2	ND	37.6	18.7	ND	2.8	0.4	3.8	ND	25.7
Hydromulch Medium Seeding	22.6	1.3	5.2	0.4	13.0	0.2	42.7	24.3	0.6	2.6	ND	0.6	ND	28.1
Hydromulch High Seeding	32.6	0.5	0.6	0.6	6.3	ND	40.6	26.2	0.2	3.0	0.2	5.8	ND	35.4
Hay Mulch Low Seeding	23.4	12.2	8.0	1.3	2.8	0.2	47.9	21.7	6.8	2.3	0.4	6.8	ND	38.0
Hay Mulch Medium Seeding	30.8	2.4	5.8	ND	3.8	ND	42.8	25.6	8.4	5.8	ND	3.2	0.8	43.8
Hay Mulch High Seeding	28.6	0.4	4.0	0.2	3.2	ND	36.4	32.5	ND	3.6	0.2	2.6	ND	38.9
Range	14-32.6	.4-12.2	.6-12.6	0-1.3	.2-13	0-.8	33.9-47.9	14.5-32.5	0-9.8	1.2-5.8	0-.6	.6-6.8	0-.8	25.7-43.8
Mean	25.5	3.8	5.3	0.5	4.4	0.2	39.5	24.1	2.9	3.1	0.2	3.5	.09	33.9

[1/] Mulch treatments and seeding rates are illustrated on Figure 6-3

Table 6-22. Results of a One-Way ANOVA Comparing Arcsine Transformed Coverage Estimates for Planted Grasses, Forbs and Shrubs Between 1977, 1978, 1979 and 1980 for Experimental Revegetation Plot R-3, Tract C-a[1/]

Growth Form	Source of Variation: Year	
	F	PR>F[2/]
Grasses	9.37*	0.0001
Forbs	2.22	0.0849
Shrubs	5.71*	0.0011

* Significant at $\alpha = 0.05$

[1/] Complete analyses are presented in Appendix 6-2.4

[2/] PR>F represents the significance probability (α) associated with F

Table 6-23. Results of a Duncan's Multiple Range Test for Significant Differences in Arcsine Transformed Coverage Estimates for Planted Grasses Between 1977, 1978, 1979 and 1980 on Experimental Revegetation Plot R-3, Tract C-a

ONE-WAY ANALYSIS OF VARIANCE BY GROWTH FORM

GR_FRM=GRASSES

GENERAL LINEAR MODELS PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE ASPC

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=297 MS=.0322422

GROUPING		MEAN	N	YEAR
	A	0.316420	34	78
	A			
B	A	0.248466	27	79
B				
B	C	0.178731	37	77
	C			
	C	0.152813	203	80

Table 6-24. Results of a Three-way ANOVA Comparing Arcsine Transformed Coverage Estimates for Planted and Invaded Grass, Forb, and Shrub Species During 1980 on Experimental Revegetation Plot R-3, Tract C-a[1/]

Growth Form	Source of Variation: Substrate		Mulch		Seeding		Substrate x Mulch		Substrate x Seeding		Mulch x Seeding		Substrate x Mulch x Seeding	
	F	PR>F[2/]	F	PR>F[2/]	F	PR>F[2/]	F	PR>F[2/]	F	PR>F[2/]	F	PR>F[2/]	F	PR>F[2/]
Grasses Planted	0.18	0.6746	0.36	0.6986	3.64*	0.0287	0.32	0.7271	0.22	0.8041	0.08	0.9874	0.49	0.7455
Grasses Invaded	0.12	0.7341	1.53	0.2393	9.41*	0.0011	0.18	0.8405	2.60	0.0967	0.41	0.7960	2.26	0.1466
Forbs Planted	0.56	0.4584	0.28	0.7595	4.18*	0.0231	0.20	0.8218	5.83*	0.0063	0.41	0.8006	0.47	0.7598
Forbs Invaded[3/]														
Shrubs Planted	0.05	0.8270	0.81	0.4501	0.23	0.7952	1.78	0.1794	0.97	0.3856	0.52	0.7195	1.67	0.1718
Shrubs Invaded[3/]	1.90	0.3998	0.24	0.8237	0.04	0.8789								

* Significant at $\alpha = 0.05$

[1/] Complete analyses are presented in Appendix 6-2.4

[2/] PR> F represents the significance probability (α) associated with F

[3/] Missing values result from insufficient data to complete the ANOVA

of Duncan's multiple range tests for these significant differences are illustrated on Table 6-25. Planted grasses had significantly higher coverage on plots seeded at a rate of 25 pounds per acre (treatment 3) than those seeded at 15 pounds per acre (treatment 1). The intermediate seeding rate (20 lb/A) (treatment 2) was not significantly different from either the high or the low rate. As might be expected, coverage of invaded grasses was the highest on the plots where the seeding rate was lowest. Coverage of invaded grasses was not significantly different between plots with the medium and high seeding rates (Table 6-25).

Results of a three-way ANOVA comparing 1980 coverage of individual planted grass species indicate that there are significant main and interaction effects for a number of species (Table 6-26). Agropyron trichophorum and Stipa virdula exhibited significant differences in coverage between control and treatment substrates. Results of Duncan's multiple range tests on these differences indicate that pubescent wheatgrass (Agropyron trichophorum) was favored over processed shale while green needlegrass (Stipa virdula) was favored on the control plots (no processed shale) (Table 6-27). It is not entirely clear why these differences occur but they are probably an artifact of the sampling procedure. Data on soil chemistry [Section 6-2, B (3) (c)] do not support the supposition that these differences are truly a result of variations in substrate.

Indian ricegrass exhibited significant differences in coverage based on both mulch and seeding treatments (Table 6-26). As illustrated by Duncan's multiple range tests, ricegrass appears to be favored on plots with hay mulch (treatment 1) and/or plots seeded at medium or high rates (treatments 2 and 3, respectively) (Table 6-28). The only other grass species which appeared to be influenced by seeding rate was pubescent wheatgrass. All three seeding rates were significantly different from one another based on coverage of this species. As might be expected, the high seeding rate (treatment 3) resulted in significantly higher coverage than either the medium or low rates (Table 6-29).

Coverage of planted forb species on all treatment combinations for the control plots ranged from 0.6 to 12.6 percent, with an average of 5.3 percent. Mean coverage on the treatment plots was slightly lower (3.1%), with a range from

Table 6-25. Results of Duncan's Multiple Range Tests for Significant Main Effect Differences in Arcsine Transformed Coverage Estimates for Planted and Invaded Grasses Among Seeding Rates for 1980 on Experimental Revegetation Plot R-3, Tract C-a

THREE-WAY ANALYSIS OF VARIANCE FOR PLANTED SPECIES
BY GROWTH FORMS

GR_FRM=GRASSES

GENERAL LINEAR MODELS PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE ASPC

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=148 MS=.0245201

GROUPING	MEAN	N	SEEDING
A	0.206405	52	3
A			
B A	0.166273	56	2
B			
B	0.125891	58	1

THREE-WAY ANALYSIS OF VARIANCE FOR INVADED SPECIES

ALPHA LEVEL=.05 DF=22 MS=.0075752

GROUPING	MEAN	N	SEEDING
A	0.169460	16	1
B	0.068635	12	2
B			
B	0.015558	9	3

Table 6-26. Results of a Three-way ANOVA Comparing Arcsine Transformed Coverage Estimates for Planted Individual Species Encountered Ouring 1980 on Experimental Revegetation Plot R-3, Tract C-a

Growth Form	Source of Variation: Substrate F	Substrate PR>F[2]	Mulch F	Mulch PR>F[2]	Seeding F	Seeding PR>F[2]	Substrate x Mulch F	Substrate x Mulch PR>F[2]	Substrate x Seeding F	Substrate x Seeding PR>F[2]	Mulch x Seeding F	Mulch x Seeding PR>F[2]	Substrate x Mulch x Seeding F	Substrate x Mulch x Seeding PR>F[2]
Grasses Planted														
Agropyron species	0.16	0.6969	2.38	0.1206	0.91	0.4212	0.15	0.8624	2.48	0.1118	1.74	0.1855	3.47*	0.0286
Agropyron trichophorum	6.54*	0.0204	1.11	0.3529	71.77*	0.0001	4.83*	0.0218	18.67*	0.0001	1.08	0.3988	0.96	0.4536
Bromus inermis	0.19	0.6660	1.28	0.3021	1.52	0.2453	2.09	0.1526	4.82	0.0210	1.06	0.4062	1.49	0.2464
Oryzopsis hymenoides	1.41	0.2502	5.25*	0.0160	12.76*	0.0004	0.89	0.4277	0.85	0.4430	0.15	0.9583	1.24	0.3309
Stipa viridula	6.76*	0.0265	3.01	0.0946	3.47	0.0715	0.17	0.8448	0.02	0.9020	0.73	0.5586	6.11*	0.0330
Planted Forbs														
Astragalus cicer	5.04*	0.0384	1.47	0.2576	5.44*	0.0149	0.59	0.5666	6.83*	0.0067	2.29	0.1018	1.03	0.4210
Linum lewisii[3]	0.71	0.5540	0.27	0.8068	0.35	0.7648	0.08	0.9309						
Melilotus officinale[3]	0.42	0.5652	0.26	0.7853	0.43	0.6851								
Planted Shrubs														
Atriplex canescens	3.16	0.1501	0.56	0.6080	0.17	0.7045	0.03	0.9664	0.01	0.9341	0.77	0.5224	1.60	0.2752
Chrysothamnus nauseosus[3]	0.02	0.9029	0.33	0.6667										
Eurotia lanata	5.14*	0.0427	2.28	0.1446	0.75	0.4933	5.91*	0.0163	1.15	0.3504	0.89	0.4982	3.93*	0.0487
Purshia tridentata[3]	0.01	0.9155	0.98	0.4697	0.16	0.8602	0.73	0.5520	3.45	0.1666	0.21	0.8216		

* Significant at $\alpha = 0.05$

[1] Complete analyses are presented in Appendix 6-2.4

[2] PR>F represents the significance probability (α) associated with F

[3] Missing values result from insufficient data to complete the ANOVA

Table 6-27. Results of Duncan's Multiple Range Tests Comparing Arcsine Transformed Coverage Estimates for Agropyron trichophorum and Stipa viridula Between Control (1) and Treatment (2) Substrates for 1980 on Experimental Revegetation Plot R-3, Tract C-a

THREE-WAY ANALYSIS OF VARIANCE BY SPECIES

SPECIES=AGROPYRON TRICHOPHORUM

GENERAL LINEAR MODELS PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE ASPC

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=17 MS=.0012853

GROUPING	MEAN	N	SUBSTRAT
A	0.184075	17	2
B	0.153077	18	1

SPECIES=STIPA VIRIDULA

ALPHA LEVEL=.05 DF=10 MS=6.4E-04

GROUPING	MEAN	N	SUBSTRAT
A	0.061323	16	1
B	0.031438	7	2

Table 6-28. Results of Duncan's Multiple Range Tests for Significant Main Effect Differences, Mulch and Seeding, in Arcsine Transformed Coverage Estimates for Oryzopsis hymenoides during 1980 on Experimental Revegetation Plot R-3, Tract C-a[1/]

THREE-WAY ANALYSIS OF VARIANCE BY SPECIES

SPECIES=ORYZOPSIS HYMENOIDES

GENERAL LINEAR MODELS PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE ASPC

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=18 MS=.0013454

GROUPING	MEAN	N	MULCH
A	0.127968	12	1
B	0.090221	12	3
B			
B	0.082669	12	2

ALPHA LEVEL=.05 DF=18 MS=.0013454

GROUPING	MEAN	N	SEEDING
A	0.133781	12	3
A			
A	0.107811	12	2
B	0.059266	12	1

[1/] Mulch and seeding treatments are illustrated on Figure 6-3

Table 6-29. Results of a Duncan's Multiple Range Test for the Significant Main Effect Difference in Arcsine Transformed Coverage Estimates Among Seeding Rates during 1980 for Agropyron trichophorum on Experimental Revegetation Plot R-3, Tract C-a[1/]

THREE-WAY ANALYSIS OF VARIANCE BY SPECIES

SPECIES=AGROPYRON TRICHOPHORUM

GENERAL LINEAR MODELS PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE ASPC

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=17 MS=.0012853

GROUPING	MEAN	N	SEEDING
A	0.254330	12	3
B	0.169305	12	2
C	0.072820	11	1

[1/] Seeding treatments are illustrated on Figure 6-3

1.2 to 5.8 percent. Coverage of planted forbs on the control area was highest for hydromulched plots with low seeding rates, and lowest for hydromulch and high rates for seeding. On the treatment plots, hay mulch and medium seeding rate resulted in the highest coverage. The lowest coverage on treatment plots was noted for the no mulch and high seeding rate combination (Table 6-21). Cicer milkvetch (Astragalus cicer) was the dominant forb species throughout R-3. Lewis flax (Linum lewisii) and yellow sweetclover (Melilotus officinale) were subordinant forbs which were commonly encountered on both control and treatment plots. The most prevalent invading forb species were Russian thistle (Salsola kali), scarlet globemallow (Sphaeralcea coccinea) and Cryptantha sericea.

A one-way ANOVA comparing coverage of all forb species between 1977, 1978, 1979 and 1980 indicates that variations for forb coverage are not significant (Table 6-22). However, the general trend for forb coverage is similar to that for grasses. Coverage for 1980 was lower than for the three other years and was the highest during 1979 when the standing crop was clipped for biomass determinations. Low coverage for 1980 may be a function of the 1979 clipping and, if this is the case, forb coverage can be expected to increase during the coming years.

Results of a three-way ANOVA comparing coverage of planted forbs on the various treatment combinations (substrate, mulch and seeding rate) indicate significant differences for the main effect, seeding, and for the substrate x seeding interaction (Table 6-24). Duncan's multiple range test results for the seeding effect indicate that coverage of planted forbs on plots with low and medium seeding rates (treatments 1 and 2, respectively) was significantly greater than on plots where the seeding rate was high (treatment 3) (Table 6-30). Low forb coverage on plots receiving the highest seeding rate may be related to competition from grass species, which tended to have the highest coverage on these plots (Table 6-25).

Of the three planted forb species which were encountered, only Astragalus cicer had significant main and/or interaction effect differences based on a three-way ANOVA using 1980 data (Table 6-26). Results of Duncan's multiple range tests on the main effect differences, substrate and seeding, are presented on Table 6-31. Coverage of cicer milkvetch was significantly higher on the control

Table 6-30. Results of a Duncan's Multiple Range Test for Significant Main Effect Differences in Arcsine Transformed Coverage Estimates Among Seeding Rates during 1980 for Planted Forbs on Experimental Revegetation Plot R-3, Tract C-a[1/]

THREE-WAY ANALYSIS OF VARIANCE FOR PLANTED SPECIES
BY GROWTH FORMS

GR_FRM=FORBS

GENERAL LINEAR MODELS PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE ASPC

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT

ALPHA LEVEL=.05 DF=37 MS=.0076173

GROUPING	MEAN	N	SEEDING
A	0.109116	17	1
A			
A	0.108287	17	2
B	0.041019	21	3

[1/] Seeding treatments are illustrated on Figure 6-3

Table 6-31. Results of Duncan's Multiple Range Tests for Significant Main Effect Differences, Substrate and Seeding, in Arcsine Transformed Coverage Estimates for *Astragalus cicer* during 1980 on Experimental Revegetation Plot R-3, Tract C-a[1/]

THREE-WAY ANALYSIS OF VARIANCE BY SPECIES

SPECIES=ASTRAGALUS CICER

GENERAL LINEAR MODELS PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE ASPC

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=17 MS=0.005036

GROUPING	MEAN	N	SUBSTRAT
A	0.148374	18	1
B	0.094500	17	2

ALPHA LEVEL=.05 DF=17 MS=0.005036

GROUPING	MEAN	N	SEEDING
A	0.147914	12	1
A			
A	0.146740	12	2
B	0.067400	11	3

[1/] Substrate and seeding treatments are illustrated on Figure 6-3

plots than over the processed shale. Soil chemistry data do not indicate significant differences between the control and treatment substrates; consequently, the reason for this difference in coverage of Astragalus is not evident. Variations in coverage based on seeding rates show that coverage is significantly higher where seeding was done at low and medium rates (treatments 1 and 2, respectively) than on plots seeded at the high rate (treatment 3). It is possible that increased grass coverage and the resultant competition on the high seeding rate plots is influencing the coverage of cicer milkvetch.

Coverage of planted shrub species on control plots ranged from 0.2 to 13.0 percent, with an average of 4.2 percent. Highest coverage was noted on the hydromulch/medium seeding treatment combination and the lowest coverage was recorded for the hydromulch/low seeding treatment (Table 6-21). High coverage on one of six of the control treatment sample plots seems to be a function of unusually high coverage of winterfat (Ceratoides lanata) and Kochia prostrata. Winterfat was planted both with seed and containerized tubelings whereas Kochia was planted only as tubelings. It appeared that random sampling on the hydromulch/medium seeding treatment encountered tubelings of both species, resulting in the inordinately high shrub coverage (Appendix 6-2.4). In addition to winterfat, the other seeded shrub species commonly encountered on both the control and treatment areas were fourwing saltbush (Atriplex canescens) and bitterbrush (Purshia tridentata). Mean coverage of shrubs on the treatment plots (3.5%) was slightly lower than on the control plots. The range in coverage was from 0.6 percent on the hydromulch/medium seeding treatment to 6.8 percent on the hay mulch/low seeding treatment. Variations between means on the control and treatment plots probably result from the unusually high coverage of Kochia and Ceratoides noted above. Coverage of invading shrubs was low on both control and treatment areas (Table 6-21).

A one-way ANOVA comparing coverage for all shrubs on R-3 for 1977, 1978, 1979 and 1980 indicates that there have been significant differences among these four years (Table 6-22). Results of a Duncan's multiple range test indicate that coverage for 1980 was significantly lower than for the previous three years (Table 6-32). Clipping of shrubs for biomass determinations during 1979 is the probable cause of reduced shrub coverage in 1980. Although recovery of shrub species is expected to be slower than that for grasses and forbs, it

Table 6-32. Results of a Duncan's Multiple Range Test for Significant Differences in Arcsine Transformed Coverage Estimates for Planted Shrubs between 1977, 1978, 1979 and 1980 on Experimental Revegetation Plot R-3, Tract C-a

ONE-WAY ANALYSIS OF VARIANCE BY GROWTH FORM

GR_FRM=SHRUBS

GENERAL LINEAR MODELS PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE ASPC

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=158 MS=.0483445

GROUPING	MEAN	N	YEAR
A	0.219215	37	78
A			
A	0.202163	29	79
A			
A	0.176531	24	77
B	0.060774	72	80

appears that shrubs have resprouted from roots and/or stem bases, and that shrub coverage will increase substantially during 1981.

Analysis of 1980 shrub coverage data using a three-way ANOVA indicates that there were no significant differences for any of the main or interaction effects when all species are lumped (Table 6-24). When individual shrub species were considered, significant differences were noted for winterfat on the main effect, substrate, and the interaction effects substrate x mulch and substrate x mulch x seeding. Table 6-33 illustrates the results of a Duncan's multiple range test on the main effect difference. Coverage of winterfat is significantly higher on the control area than on the treatment area. Because there are no significant differences in soil chemistry between the control and treatment areas, the reason for differences in winterfat coverage between the two areas is unclear.

b. Precipitation at Plot R-3 - Rainfall recorded at two locations on R-3 from April through October, 1980, ranged from 8.12 to 8.42 inches. The highest monthly mean (2.72 in) occurred during August when two major precipitation events were recorded at Meteorological Monitoring Site 2. Total precipitation for June (0.03 in) was the lowest monthly total recorded. Low precipitation during June is similar to precipitation noted for 1979, but August rainfall appears to be higher than that typically encountered on Tract C-a.

c. Soil Chemistry from Plot R-3 - Soil samples were collected during October 1980. Data are included in Appendix 6-2.5 and statistical analyses are presented in Appendix 6-2.6.

Physical and chemical analyses included determinations for texture, cation exchange capacity, conductivity, sodium, lime, organic matter, organic nitrogen, NO_3, P, K, Ca, Mg, S, B, Zn, Fe, Mn, Cu, As, F, Mo and Se. Statistical comparisons (t-tests) between the control and treatment areas for corresponding sample depths showed no significant differences for any of the above constituents. These data indicate that the reconstructed soil profile over Tosco II processed shale is functioning as an effective barrier to vertical migration of chemical constituents from the processed shale into the surface growth medium.

Table 6-33. Results of a Duncan's Multiple Range Test Comparing Arcsine Transformed Coverage Estimates for Ceratoides lanata Between Control (1) and Treatment (2) Substrates for 1980 on Experimental Revegetation Plot R-3, Tract C-a

THREE-WAY ANALYSIS OF VARIANCE BY SPECIES

SPECIES=EUROTIA LANATA

GENERAL LINEAR MODELS PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE ASPC

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=12 MS=.0041081

GROUPING	MEAN	N	SUBSTRAT
A	0.123595	14	1
B	0.068673	14	2

Electrical conductivity has been measured on an annual basis for R-3 since 1976. The 1980 values are similar to those reported for 1979 (Table 6-34). Data from both 1979 and 1980 illustrate that conductivity has increased from 1976 through 1978. Because conductivity increases occurred on both the control and treatment sites, it is likely that these increases are related to analytical techniques rather than sampling procedures and/or substrate differences. Conductivities ranging between 0 and 2 μmhos are not expected to influence plant growth.

Table 6-34. Average Electrical Conductivity (μmhos/cm)[1/] of Soils Sampled at Three Depths (0, 25, 50 cm) at RBOSC Revegetation Plot R-3 During Fall 1976, 1977, 1978, 1979, and 1980, Tract C-a[2/]

	Substrate									
	Treatment (Processed Shale)					Control (No Processed Shale)				
Depth	1976	1977	1978	1979	1980	1976	1977	1978	1979	1980
0	.28	.20	.26	1.10	1.3	.26	.20	.28	.85	1.1
25	.38	.26	.28	1.55	1.3	.31	.26	.27	1.10	1.2
50	.45	.50	.40	1.50	1.7	.56	.57	.42	2.45	2.0

[1/] Based on a 1:2 soil-water extract

[2/] 1979 data differ in sampling technique, location, and number of replications and, consequently, are not directly comparable to data from previous years.

6.3 SUBSIDENCE MONITORING (MIS Area)

1. Objectives

Subsidence monuments were installed and are measured on a periodic basis to determine if any surface displacement occurs due to the dewatering effort, retort preparation, the burning of the retorts, or from any other unforeseen cause.

2. Methods

A survey monument grid was placed on the ground surface over each MDP retort area prior to its rubblization. Additional monuments were placed in various other areas to determine the effects of dewatering. These monuments consist of a one-inch rebar pin anchored with resin inside a three-inch casing. The coordinates and elevation of each of the monuments were established and reported in MDP Monitoring Report 4 (RBOSC 1979b). RBOSC determined the horizontal and vertical relationship of these monuments to a primary control point sufficiently distant from the retorts to assure that the primary control point does not itself undergo any horizontal or vertical displacement due to MIS activities.

The requirements for subsidence monitoring were reduced slightly during 1980. Until the change RBOSC was required to check each monument for vertical and horizontal movement every six months. All monuments are now surveyed for vertical movement every six months and for horizontal movement once a year.

During six-month surveys, monuments are checked for movement relative to a secondary control point at the intersection of the old Airplane Ridge Road and the main access road. The reason that this control point was selected was to reduce the time required for routine checking of the monuments, since it is considerably closer to the site than the primary control point which is located south of the MIS area. If movement is noted during the six-month surveys, then a check from primary control will be necessary to insure that the secondary control has not moved. If substantial movement is confirmed, the topography of the affected area will be re-mapped in appropriate detail by plane table or other

suitable means. Third order surveying accuracy control will be used for all vertical and horizontal control work.

As of June 1979, 50 monuments were in existence. Construction activities have subsequently destroyed six monuments, leaving 44 monuments as of December 1980. These monuments are currently monitored (Figure 6-4).

3. Results

A survey of the vertical movement of all 47 existing monuments was conducted in June of 1980. A survey of the horizontal movement of 24 randomly selected monuments was also conducted at that time. During December of 1980, identical vertical and horizontal surveys were conducted on 44 and 19 (randomly selected) monuments respectively. No monument movement was detected in either of these surveys.

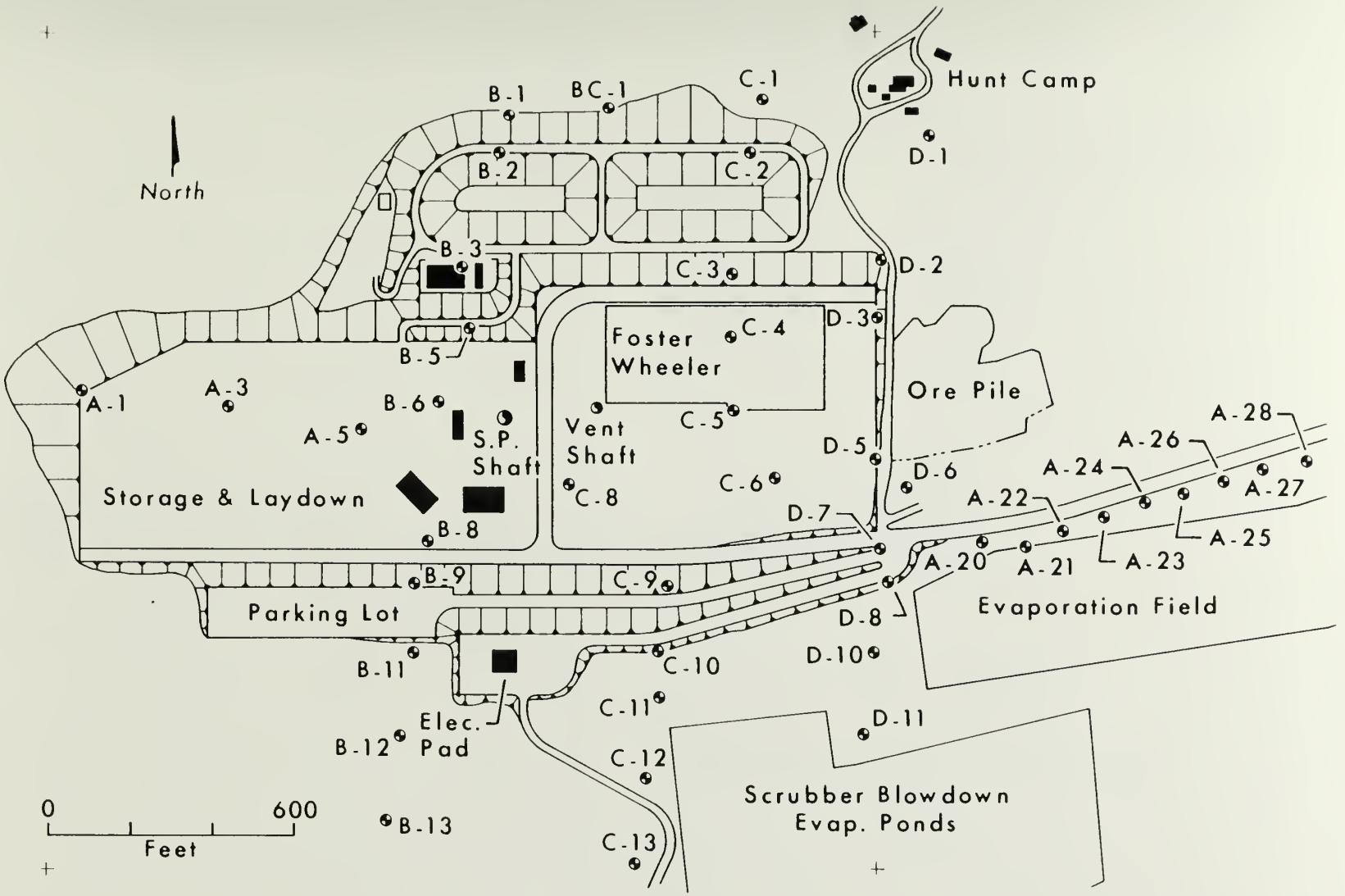


Figure 6-4. Subsidence Monument Location Map.

6.4 RUN-OF-MINE LYSIMETER STUDY

RBOSC has negotiated with the EPA, USGS and the DOE Task Force to conduct leaching studies on stock-piled run-of-mine ore. As a part of this agreement, RBOSC constructed the leaching apparatus in the stockpile. The cooperating government groups will collect and analyze the leachate.

The objective of this study is to determine the chemical characteristics of leachate generated from raw shale in the field and to compare these results with those from laboratory tests on the same materials. This comparison is being conducted to determine the importance of such factors as percolation rates (residence times), wetting and drying cycles, and other weathering factors on leachate quality.

The field collection system consists of three collectors buried beneath the raw shale pile at depths of 5, 10, and 15 feet. Each collector consists of a 10 x 10 foot square teflon sheet, contoured so that the percolating water is intercepted and conducted to a teflon drain pipe located at the center of the collector (Figure 6-5).

A flow-through electrical resistance probe and a thermocouple have been placed in the teflon collection line to measure conductivity and temperature. Recording rain gages document precipitation quantity in the area of the pile. Snow depths are periodically recorded.

Samples are collected after a precipitation event by the USGS and split for distribution to the involved researchers. Samples are then analyzed for the constituents indicated on Table 6-35.

The field lysimeter tests were initiated in mid-June 1980. To date, adequate samples have not been collected at the 10 and 15 ft. intervals to conduct the analyses. One composite sample was collected, however, on August 26, 1980 from the lysimeter network at the 5 ft. depth interval. Approximately 20 liters of leachate had accumulated by that date. Most of this leachate was produced following a 0.5+ in. rainstorm on August 15, 1980. Samples of the leachate were collected and analyzed by the USGS. Results of this testing are shown in Table 6-35.

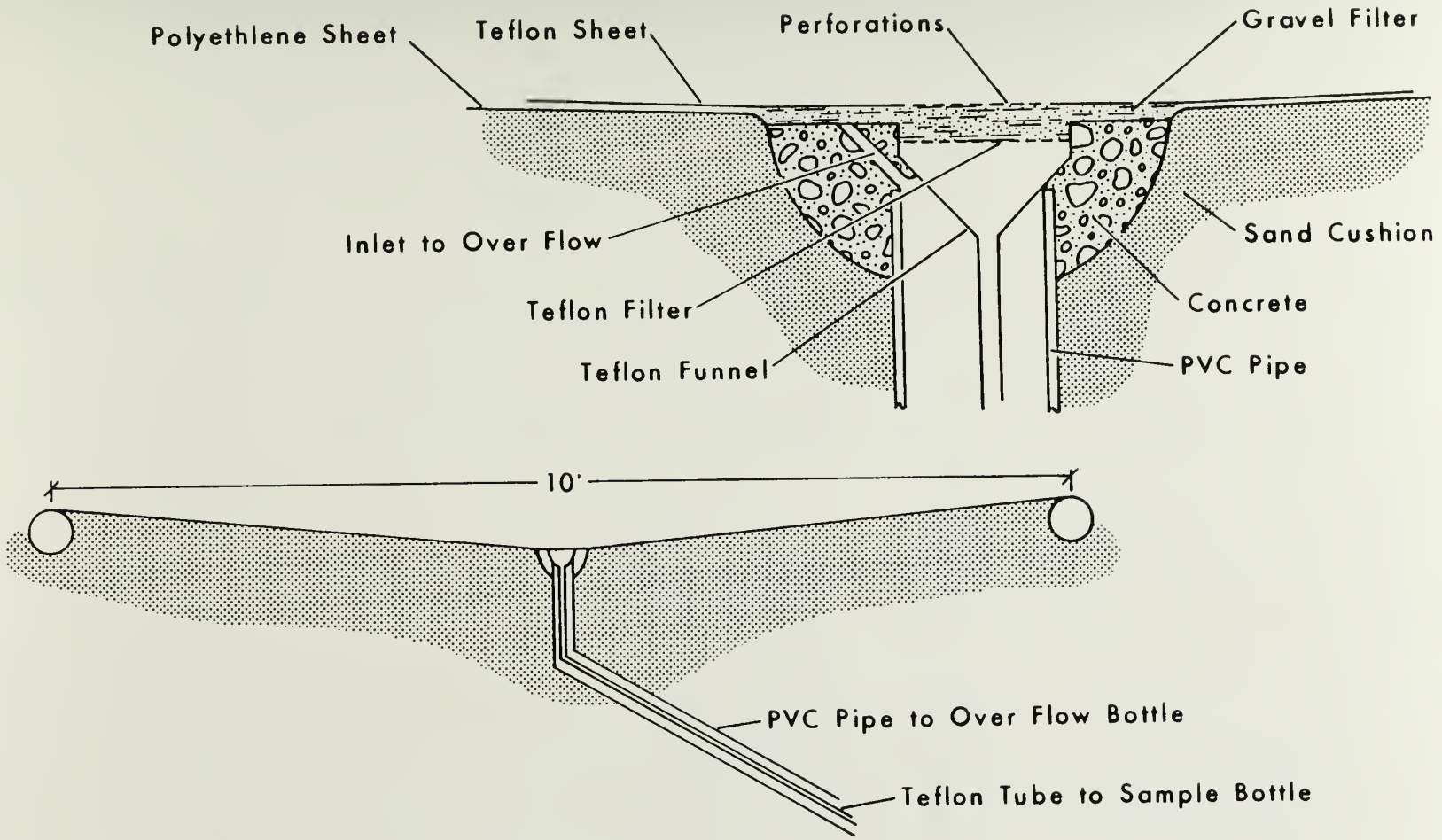


Figure 6-5. Construction Details of the Buried Collectors - Tract C-a.

Table 6-35. Leachate Water Quality Data from the Tract C-a Run-of-Mine Stockpile Field Lysimeter Study - 5 ft. Depth (June 18 - August 26, 1980)

Constituent	Concentration[1/2/]	Constituent	Concentration[1/2/]
Alkalinity (mg/l as $CaCO_3$)	48	Nitrate-nitrite (as N)	45
Aluminum	10	Ammonia (as N)	4.6
Arsenic	2	Kjeld-N (as N)	9.1
Barium	100	DON (as N)	4.5
Beryllium	0	Total Nitrogen (as N)	54
Boron	150	pH (field)	7.7
Cadmium	0	pH (lab)	7.1
Calcium (mg/l)	440	Phenols	3
DOC (mg/l)	13	Total Phosphorus (mg/l)	0.00
Chloride (mg/l)	29	Potassium (mg/l)	3.5
Chromium	0	Potassium 40 (pc/l)	2.6
Cobalt	100	TDS (calculated) (mg/l)	3490
Copper	8	SAR	1.6
Fluoride (mg/l)	2.4	Selenium	0
Hardness (Non-carbonate)(mg/l)	2300	Silica (mg/l)	4.6
Hardness (Total) (mg/l)	2300	Sodium (mg/l)	180
Iron	60	Sodium (%)	14
Lead	0	Spec. cond. (field)(μmhos/cm)	3950
Lithium	50	Spec. cond. (lab)(μmhos/cm)	3877
Magnesium (mg/l)	300	Strontium	3000
Manganese	220	Sulfate (mg/l)	2300
Mercury	0.0	Vanadium	4
Molybdenum	270	Zinc	50
Nickel	37		

1/ All concentration expressed for dissolved fraction only

2/ Concentrations expressed in μg/l unless listed otherwise

Table 6-36 compares the tests results from Table 6-35 with laboratory leaching tests of C-a shale and with Colorado water quality standards. Generally, the concentration of constituents in the field lysimeter samples was lower than or in the range of values reported from the laboratory tests. This may be due, in part, to the difference in the size fractions of materials used in the two respective tests. For the laboratory tests, the shale was crushed to approximately one inch nominal diameter. Field tests were on run-of-mine material having a nominal diameter of about two inches. Thus, the surface area would be greater for test materials in the lab test than in the field studies. Consequently, the more concentrated leachates from the laboratory test may have resulted from greater contact of the leaching medium (deionized water) with the test material.

Comparison of the lysimeter data with Colorado primary drinking water regulations show that all concentrations of trace metals except manganese are below the drinking water limitations.

Although the concentration of nitrate, sulfate, and fluoride exceed drinking water standards, the concentrations of these anions in the leachate are similar to those found in lower aquifer waters in the region. These concentrations would not pose a serious water pollution problem if leachate entered the natural surface or subsurface hydrologic system.

Table 6-36. Comparison of Field Lysimeter Data with Laboratory Data and Drinking Water Standards

Parameter	Units	C-a Lysimeter Study	C-a R-5/Mahog. Shale	C-a Composite	Colorado Drinking Water Criteria
Al	mg/l	0.01	0.3 - 3.53	<0.05 - 0.69	---
As	mg/l	0.002	<0.005	<0.005	0.05
B	mg/l	0.150	<0.025 - 0.59	<0.025 - 1.97	---
Ba	mg/l	0.100	0.088 - 0.27	0.027 - 0.22	1.0
Be	mg/l	0.000	<0.025	<0.025	---
Ca	mg/l	0.000	180 - 1510	18 - 970	---
Cl	mg/l	29	1.9 - 300	0.3 - 130	---
CO_3	mg/l	-	<0.1 - 346	0.3 - 0.7	---
Cr	mg/l	0.000	0.022 - 0.034	<0.025 - 0.043	0.05
Cu	mg/l	0.008	<0.025 - 0.69	<0.025 - 0.44	1.0
EC	µmhos/cm	3900	1900 - 37000	125 - 8200	---
F	mg/l	2.4	0.8 - 65	<0.5 - 3.0	1.8
Fe	mg/l	0.060	<0.1	<0.1	0.3
HCO_3	mg/l	-	3.0 - 403	82 - 1026	---
Hg	mg/l	0.000	<0.0001	<0.0001	0.002
K	mg/l	3.5	8.2 - 640	0.4 - 34	---
Li	mg/l	0.050	0.02 - 0.11	<0.02 - 0.79	---
Mg	mg/l	300	0.675 - 108	4.9 - 820	---
Mn	mg/l	0.22	<0.05 - 0.35	<0.05 - 0.40	0.05
Mo	mg/l	0.27	0.10 - 5.18	0.10 - 2.2	---
Na	mg/l	180	27 - 7710	4.3 - 1240	---
Ni	mg/l	0.037	0.047 - 0.085	<0.05 - 0.16	---
NO_3	mg/l	45	4 - 172	<0.5 - 140	10
Pb	mg/l	0.000	<0.05 - 0.83	<0.05 - 0.77	0.05
pH	---	7.7	6.93 - 11.98	7.03 - 7.99	---
Se	mg/l	0.000	<0.005	<0.005	0.01
Si	mg/l	4.6	1.2 - 23.28	5.8 - 19.58	---
Sn	mg/l	-	---	---	---
SO_4	mg/l	2300	5 - 6600	7.9 - 6100	250
TDS	mg/l	-	610 - 30130	164 - 9450	500
Zn	mg/l	0.050	<0.01 - 0.09	<0.02 - 1.5	5.0

6.5 MULE DEER HABITAT MODIFICATION STUDY

1. Objectives

During RBOSC's commercial operation, land will be disturbed, resulting in a loss of forage for wildlife, primarily mule deer. One means of mitigating these losses is to increase the mule deer carrying capacity of undisturbed areas to maintain overall carrying capacity at, or near, predevelopment levels. RBOSC initiated an experiment in 1980 to determine the feasibility of producing such increases in carrying capacity using the habitat modification techniques described below.

2. Methods

The critical factor which currently limits mule deer populations in the Piceance Creek Basin is the availability of suitable food during periods of heavy snow cover. Thus, a program designed to increase the carrying capacity of local habitats for mule deer should be aimed at increasing suitable forage as well as providing access for mule deer to these modified areas during periods of heavy snow cover. Habitat modification in large, continuous blocks increases wildlife forage, but such large areas commonly fill with snow during periods of heavy snowfall making the area inaccessible to deer. The RBOSC habitat modification program is designed to avoid this problem by modifying vegetation in strips, leaving the vegetation between strips undisturbed. The undisturbed strips provide cover and access routes to the modified areas.

The 1980 habitat modification experiment was established October 22-23 in the SE¼, SE¼ of Section 1, T2S, R99W in Stake Springs Draw (Figure 6-6). This area includes a valley bottom with dense, uniform sagebrush, a south-facing slope offering several browse species palatable to mule deer and a travel lane between the bedding area and feeding area, and a north-facing slope characterized by desirable forage species. The experiment was designed to evaluate the effects of several factors critical to increasing deer carrying capacity: 1) snow depth, 2) moisture availability during the growing season, 3) selective brush removal, 4) quality forage, and 5) fertilization.

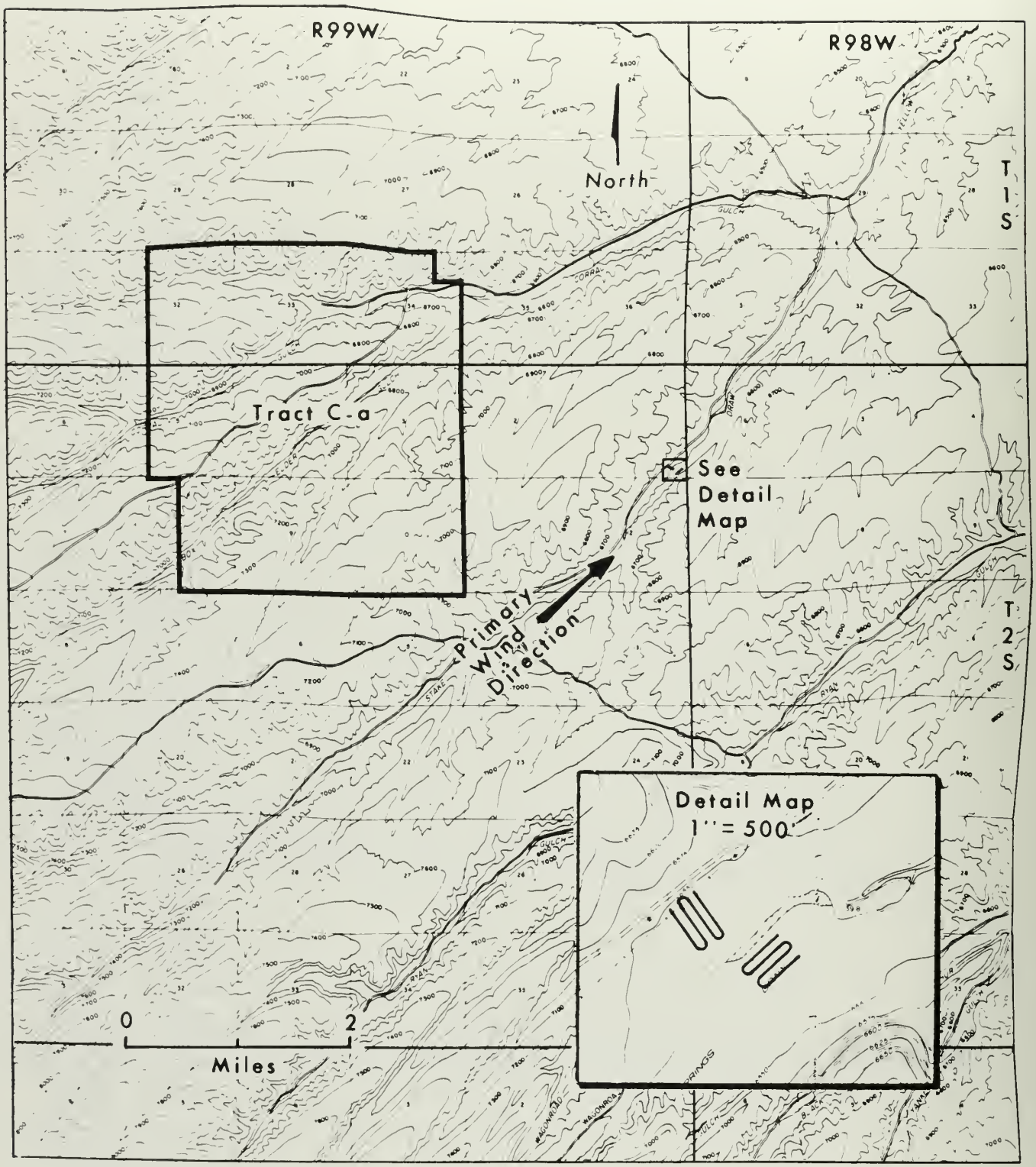


Figure 6-6. Wildlife Habitat Modification.

To increase desirable forage production, it was necessary to remove the rank sagebrush, thereby reducing plant competition. To do this, two Marden Model L-7 roto-choppers (filled with water for additional weight) were pulled behind a John Deere 450 dozer. Four narrow corridors were chopped in each of two treatment areas within the valley bottom (Figure 6-7 and 6-8). The corridors in the treatment area adjacent to the south-facing slope were oriented perpendicular to the draw and the direction of most winter winds; those in the treatment area adjacent to the north-facing slope were aligned parallel to the direction of most winter winds. A differential accumulation of snow should occur between the two areas, enabling an evaluation of the effects of such accumulation on forage production and utilization as well as deer movement.

Half of each treatment area parallel to the corridors was seeded, as shown in Figure 6-8. The treated corridors and the untreated sagebrush zones between them were broadcast seeded with the seed mixture illustrated on Table 6-37. Half of each treatment area perpendicular to the corridors will be fertilized with ammonium nitrate (33.4% nitrogen) at 120 pounds per acre, in the spring of 1981 (Figure 6-8). Both the chopped corridors and the undisturbed sagebrush between them will be fertilized.

The treatments which were established are listed below.

- chopped
- chopped and seeded
- chopped, seeded, and fertilized
- chopped and fertilized
- unchopped
- unchopped and seeded
- unchopped, seeded, and fertilized
- unchopped and fertilized

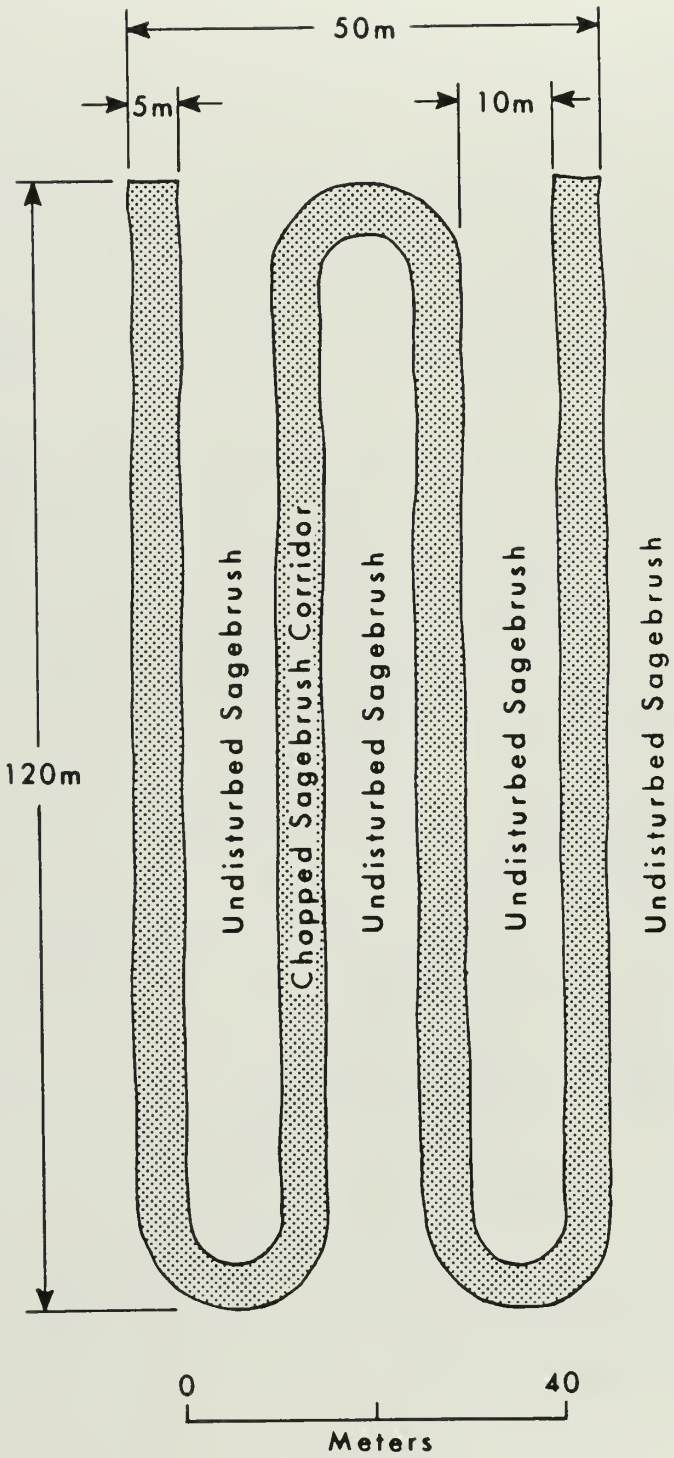


Figure 6-7. Configuration of Roto-Chopped Corridors in Area of Uniform, Dense Sagebrush in Stake Springs Draw.

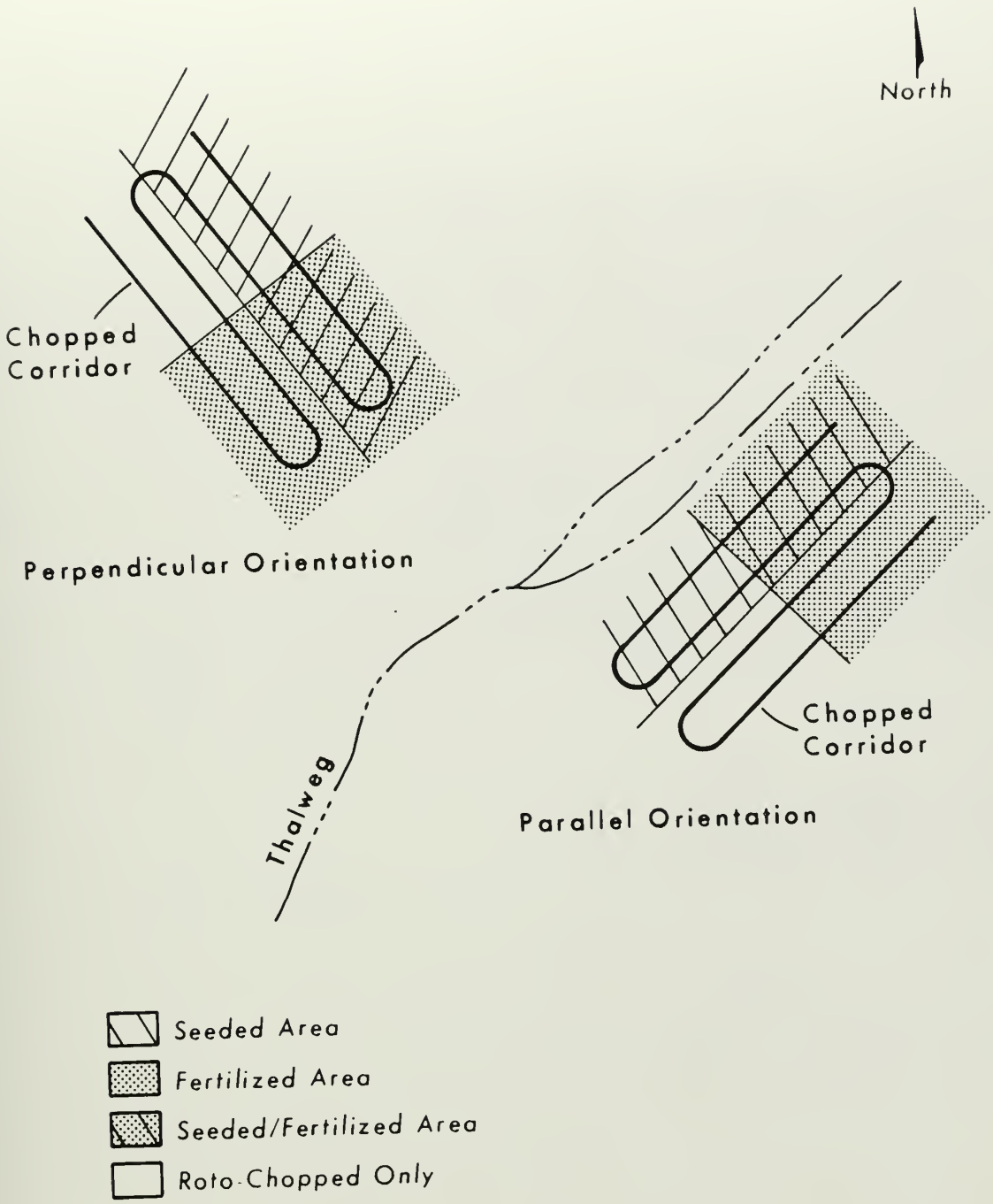


Figure 6-8. Configuration of Seeding & Fertilizing Treatments in Deer Mitigation Study.

Table 6-37. Plant Species Broadcast Seeded in the Roto-Chop Experiment Area in Stake Springs Draw

SPECIES		POUNDS PER ACRE
Grasses		
Crested wheatgrass (Agropyron desertorum)		2
Pubescent wheatgrass (Agropyron trichophorum)		1
Western wheatgrass (Agropyron smithii)		3
Indian ricegrass (Oryzopsis hymenoides)		1
Russian wildrye (Elymus junceus)		5
	Subtotal	12
Forbs		
Alfalfa (Medicago sativa)		3
Cicer milkvetch (Astragalus cicer)		1
	Subtotal	4
Shrubs		
Four-wing saltbush (Atriplex canescens)		2
Winterfat (Ceratoides lanata)		2
	Subtotal	4
	TOTAL	20

Control areas were also established in undisturbed sagebrush adjacent to each of the treatment areas.

3. Results

Before roto-chopping, 12 permanent vegetation transects (Figure 6-8) were established (four in each treated area and two in each control area) to analyze changes in the vegetation community. Three parameters (density of shrub species, percent cover of shrub species, and percent cover of herbaceous species) were estimated within eight plots on each transect. These parameters will be estimated at the end of each subsequent growing season. Any significant changes in the vegetation community will be reported in upcoming reports.

Deer utilization of the treatment and control areas will also be estimated by periodic photographs from a permanently established point. The results of these surveys also will be reported.

6.6 SUMMARY

Toxicology studies of oil shale and related materials have been and are being conducted to assess the potential health hazards associated with these substances. Studies being conducted by the American Petroleum Institute (API) and the Department of Energy (DOE) are most relevant to RBOSC, as both programs include tests of material from Tract C-a.

In 1976, the API initiated a program to investigate selected toxicological properties of oil shale and related materials. Samples included raw shale from Tract C-a. The first phase of the program is complete and results have been published (Weaver and Gibson 1979). Exposure of test organisms to raw and processed shale dust (two year inhalation studies) showed no evidence of carcinogenesis or progressive fibrotic lung disease. Dermal application of the same material yielded similar results regarding carcinogenicity. Similar dermal tests showed, however, that raw shale oil is highly carcinogenic. It is anticipated that the results of ongoing tests of refined shale oil will show that the refining process reduces this carcinogenicity.

Tests of the teratogenic affects of raw shale, processed shale, and raw shale oil showed no deformities, although some fetal toxicity was noted at the higher doses of raw shale oil. Tests of the mutagenic properties of raw shale oil were positive, weakly positive or negative, and positive in the bacterial assays, mouse lymphoma assays, and cytogenetic assays, respectively.

Tests of the acute oral and dermal toxicity of raw shale oil established respective $LD_{50's}$ (dose at which 50 percent of test animals die) of 8-10 g/kg and 5-20 ml/kg. Histopathological studies of organisms exposed to toxic concentrations revealed extensive liver damage.

Eye irritation, dermal irritation, and skin sensitization tests involving raw and processed shale dust and raw shale oil yielded generally negative results, with the exception of several minor reversible irritation effects. Application of raw shale oil at 0.5 g/72 hours produced dermal irritation.

The tests conducted under the DOE program have been initiated but results are not yet available.

Experiments were initiated during 1975 and 1976 on three revegetation demonstration plots on Tract C-a. Plots R-1 and R-2 serve to demonstrate reclamation feasibility and species adaptability with varying mulch types, fertilizer applications and plot aspects. Plot R-3 was designed to simulate a processed shale disposal site and to test the effects of a reconstructed soil profile (including capillary barrier over processed shale) on reclamation success. Various seeding rates and mulch types also were tested on plot R-3.

Plot R-1, located on a northwestern exposure, had an average coverage of 40 percent for all species encountered during 1980. Planted grass species, primarily Indian ricegrass (Oryzopsis hymenoides) and wheatgrass (Agropyron) species, accounted for 45 percent of this average. For 1980 data, there were no significant differences ($\alpha = 0.05$) in grass coverage among the 16 different treatment combinations. However, based on four years of data, analyses indicated that coverage of planted grasses during 1980 was significantly higher than for all other years. This increase seems to be related to mulch and/or fertilizer treatments. Straw mulch with netting exhibited significantly higher grass coverage than straw mulch followed by crimping. Plots with no fertilizer had significantly higher grass coverage than those fertilized at the time of sowing.

Coverage of planted forb species averaged 9.8 percent and accounted for 24 percent of total coverage on plot R-1. Lewis flax (Linum lewisii), cicer milkvetch (Astragalus cicer var. Lutana) and yellow sweetclover (Melilotus officinale var. Madrid) accounted for the majority of this coverage. For 1980 data, coverage of planted forbs was significantly higher ($\alpha = 0.05$) on plots fertilized at the time of sowing than where no fertilizer was used; however, there were no significant differences for the other two fertilizer treatments. Comparing all four years of data, 1980 coverage of planted forbs was significantly higher than all other years. Concomitant with this increase, coverage of invaded forbs was significantly lower than for previous years. Forb coverage over four years of data was linked to mulch and fertilizer treatments. Significantly higher coverage of invaded forbs was evident on plots with no mulch

and/or hydromulch as compared to either of the straw mulch treatments. Treatment combinations having either no fertilizer or fertilizer at the beginning of the first year of growth exhibited significantly lower coverage of invaded forbs than plots fertilized only at the time of sowing.

Shrub coverage on R-1 averaged 2.9 percent during 1980. Rabbitbrush species (Chrysothamnus nauseosus and C. viscidiflorus) and winterfat (Ceratoides lanata) were the dominant shrub species encountered. No significant differences in shrub coverage were noted among 1980 data but, comparing the four years of study, shrub coverage was significantly higher ($\alpha = 0.05$) in 1977, 1978 and 1980 than during 1976. Based on these data, coverage of shrubs was significantly higher on the no mulch treatments than for any of the mulch amendments. Coverage was similar for most fertilizer treatments but was significantly higher on plots fertilized at the time of sowing than on those fertilized at the beginning of the first full growing season.

On plot R-2 coverage of all species averaged 37.1 percent during 1980. Planted grasses, primarily wheatgrasses and Indian ricegrass, accounted for 41 percent of average vegetational coverage. No significant differences in grass coverage were noted among treatment combinations for 1980 data. However, coverage during 1980 was significantly higher ($\alpha = 0.05$) than for 1976, 1977 or 1978. Coverage of invading grasses was significantly higher in 1980 and 1976 than during the other two years of study. Differences in grass coverage appear to be related to mulch and/or fertilizer treatments. Significantly higher coverage of planted grasses was noted on plots without fertilizer than on plots fertilized at the time of sowing. Coverage of invading grasses was significantly higher on plots with crimped straw mulch than on those with either no mulch or hydromulch.

Planted forbs on R-2 averaged 8.3 percent coverage, or approximately 22 percent of the total coverage. Dominant species were similar to those encountered on R-1. No significant differences were noted among planted forb species for the different treatment combinations based on 1980 data. Invaded forb species exhibited significantly higher coverage ($\alpha = 0.05$) on plots with no mulch than those which had been hydromulched. When data for all years were considered, coverage of planted forbs in 1980 was significantly higher than all other

years. Coverage of invaded forbs was similar to that during 1976 but was significantly lower than during either 1977 or 1978. Variations in coverage of invaded forbs over the four year period appear to be related to mulch treatments. Coverage on plots with no mulch was significantly higher than on the hydromulched treatment.

Shrub coverage on plot R-2 averaged 6.2 percent for 1980. Rabbitbrush species and winterfat were the dominant shrubs throughout the plot. Based on 1980 data, no significant differences in coverage were noted among the 16 treatment combinations. For four years of data, shrub coverage was significantly higher ($\alpha = 0.05$) in 1978 than for 1976, 1977 or 1980. Coverage during 1976 was significantly lower than all other years. Significant differences noted over four years appear to be related to mulch treatments. Coverage on no mulch and hydromulch treatments was significantly higher than either of the straw mulched treatments.

Coverage of all species present on plot R-3 during 1980 averaged 33.8 percent on the treatment portion and 39.5 on the control portion. There were no significant differences in coverage between control and treatment plots based on coverage of all species. However, when grass species were compared over four years, 1980 coverage was significantly lower ($\alpha = 0.05$) than during 1978 or 1979. Low coverage in 1980 may be due to clipping plots for biomass determinations in 1979. Wheatgrass species and Indian ricegrass were the dominant planted grasses, and their coverage, as well as that of invading grasses, seemed to be dependent on seeding rates. The high seeding rate resulted in significantly higher coverage of planted grasses than the low rate. Invaded grasses, primarily cheat-grass (Bromus tectorum) and crested wheatgrass (Agropyron cristatum), exhibited significantly higher coverage on plots with the low seeding rate than those with either medium or high seeding rates.

Pubescent wheatgrass (Agropyron trichophorum) and green needlegrass (Stipa viridula) exhibited significant differences ($\alpha = 0.05$) between control and treatment portions of Plot R-3 during 1980. Pubescent wheatgrass appeared to be favored on the portions underlain by processed shale whereas green needlegrass exhibited significantly higher coverage on the control portion. These differences

do not appear to be related to differences in soil chemistry and consequently probably are artifacts of the sampling technique rather than the result of differences in the treatment and control plots. Indian ricegrass appears to be favored on plots with hay mulch and/or plots seeded at medium or high rates. Significantly higher coverage of pubescent wheatgrass was noted on plots seeded at the high rate than on those seeded at medium or low rates.

Coverage of planted forb species on R-3 averaged 5.3 percent on control plots and 3.1 percent on treatment plots. Cicer milkvetch was the dominant forb throughout R-3 but Lewis flax and yellow sweetclover also were commonly encountered. Forb coverage (all species lumped over all treatments) during 1980 was not significantly different ($\alpha = 0.05$) from that noted during previous years; however, slight decreases were recorded and are probably due to clipping plots for biomass determinations during 1979.

Based on 1980 data lumped by growth form, coverage for all planted forb species was significantly higher ($\alpha = 0.05$) on plots seeded at low or medium rates than on those seeded at the high rate. Cicer milkvetch, when considered without other planted forbs, followed this trend but the other two planted forb species encountered showed no significant difference in coverage based on seeding rate. Cicer milkvetch also exhibited significant differences between control and treatment substrates. Because no differences were detected in soil chemistry between these substrates, the reasons for variations in coverage are not clear.

Coverage of planted shrub species was 4.4 percent on the control and 3.5 percent on the treatment portion of R-3. Winterfat, fourwing saltbush (Atriplex canescens) and bitterbrush (Purshia tridentata) were common on both control and treatment plots. Coverage during 1980 was significantly lower ($\alpha = 0.05$) than for 1977, 1978 or 1979, and may be due to clipping of plots during 1979. No significant differences in shrub coverage (lumped for all planted species) were noted for mulch and/or seeding rates. However, when individual shrub species were considered, winterfat had significantly higher coverage on the control plots than on the treatment plots. As noted for other species, this difference in coverage between substrates does not appear to be related to soil chemistry.

No significant differences (α = 0.05) were noted between soil samples collected on control and treatment portions of R-3. Analyses included electrical conductivity, boron, fluoride, molybdenum, selenium and arsenic, among others. Data suggest that the reconstructed soil profile is functioning as a satisfactory growth medium and that the capillary barrier incorporated in the profile is inhibiting vertical movement of soluble constituents from Tosco II processed shale into the surface growth medium.

Subsidence monitoring is conducted at Tract C-a to determine if any surface displacement has occurred due to the dewatering effort, retort preparation or burning, or any other unforeseen cause. Monitoring is accomplished by surveys of monuments established prior to retort preparation. All monuments are surveyed for vertical movement every six months and for horizontal movement once a year. Surveys were conducted in June and December of 1980. No monument movement was detected.

The run-of-mine ore stockpile lysimeter study is designed to establish the chemical characteristics of leachate generated from raw shale in the field, and to compare such characteristics with those of leachate generated from raw shale in the laboratory. This comparison will enable a determination of the effects on leachate quality of factors such as percolation rates, wetting and drying cycles, and natural weathering.

The lysimeter study was initiated in June 1980. Lysimeters were installed at depths of 5, 10, and 15 feet. Samples are collected by the USGS after each precipitation event and distributed for analysis. To date, adequate leachate for analysis has accumulated only at the 5 foot level. Results of analysis of approximately 20 liters of this leachate indicated constituent concentrations generally lower than those exhibited by laboratory-generated leachate. This difference may be partially due to the lower average surface area per unit weight of the field shale as opposed to the laboratory shale.

Comparisons of the results of lysimeter leachate analyses to Colorado primary drinking water standards show the concentrations of all trace metals except manganese to be below the standards. Concentrations of nitrate, sulfate, and

fluoride exceed the standards, but approximate those exhibited by lower aquifer water at Tract C-a.

The mule deer habitat modification study is designed to determine the feasibility of increasing the wildlife carrying capacity of Tract C-a habitats by application of vegetative manipulation, fertilization, and seeding techniques. Such increases offer a means of mitigating development-related loss of wildlife habitat.

The habitat modification experiment was initiated in October 1980 in Stake Springs Draw on Tract C-a. Two treatment areas were established. Within each area, narrow corridors were chopped in the sagebrush, leaving the vegetation undisturbed between the corridors. Corridors in one area were oriented parallel to the direction of the draw (and most winter winds); those in the other, perpendicular to the same. Half of each area was then seeded with a wildlife-oriented seed mix, and half of each area will be fertilized in the spring of 1981, completing a full range of treatments. Control areas were also established adjacent to each treatment area.

The success of the experiment will be measured by estimating forage production and mule deer utilization. Shrub density and cover and herbaceous cover were estimated prior to treatment, and will be re-estimated after each growing season. Mule deer utilization will be estimated by periodic photographs from an established point. The results of these investigations will be included in future reports.

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SECTION 7
ECOLOGICAL INTERACTIONS

The identification and quantification of ecological interactions on the oil shale lease tracts and the surrounding terrain is an intriguing challenge. RBOSC and other oil shale lessees have been seeking a better understanding of these interactions for quite some time. These efforts are confounded not only by the complexity of the ecosystems under study, but also by the sheer size of the study areas -- in excess of 81 sq mi in and around Tract C-a.

Ecological interactions cannot be measured or monitored directly. Instead, they are identified through a systematic time-consuming process involving the identification of effector and receptor components of the ecosystem, collection of data on such components, assimilation of data, feedback, and data analysis. RBOSC's environmental monitoring program is providing data on a number of major ecosystem components; however, it is not possible to examine all the interactive components of the ecosystem.

The statistical analyses of interacting components must often be delayed until an adequate data set has been collected. In a study area as large and complex as RBOSC's, a large amount of natural variability can be expected, and years of data are required to separate changes in natural variability from development related impacts. This is especially true for biological parameters which must be segregated into logical functional groups (e.g. seasons, years, reproductive phase, etc.) before meaningful analyses can be accomplished.

Assimilation and synthesis of data for this and previous reporting periods has begun to confirm conceptual models developed from baseline data (RBOSP 1977) and to reveal certain (tentative) trends. Many of these trends are discussed specifically and at greater length in the various technical sections of this report.

There are a large number of interactions that could be expected to occur within the ecosystem dynamics of Tract C-a. This report will concentrate on two interactions of specific interest. They are:

- Interaction of moisture (precipitation) and range productivity

- Interaction of the mule deer population and browse utilization

The discussion provided herein is based on established ecological theory and data collected in the monitoring program between 1978 and 1980. There is no question that the Tract C-a ecosystem is subject to many more interactions than the two listed. However, because of the importance of water to vegetational communities and the influence that mule deer population size has on utilization of browse species these two interactions are of particular interest.

7.1 INTERACTION OF PRECIPITATION AND RANGE PRODUCTIVITY

A discussion of the number of precipitation events and the amount of precipitation recorded during this and previous reporting periods is provided in Section 2.2 of this report. Section 3.1-C discusses the characteristics of range productivity and utilization in 1980 for Tract C-a. The purpose of this section is to examine the interactive components between these two variables over a three year period (1978-1980) in the Tract C-a ecosystems. Before a discussion on the interactive components of these two variables can be introduced, a review of the productivity and precipitation data over the period 1978-1980 is necessary.

Precipitation over the period 1978-1980 averaged approximately 12 inches per year, as measured by a wedge gauge. There appears to be a distinct seasonal precipitation pattern, with a maximum in the spring (Table 7-1; Figure 7-1). The spring season (March, April, May) averages approximately 4.9 inches. This is approximately twice that of each of the other seasons (Table 7-1).

Precipitation during the spring season increased from 4.27 to 5.44 inches between 1978 and 1979 and decreased to 4.99 inches in 1980. For the summer season of June, July and August precipitation increased from 1.82 to 2.28 inches between 1978 and 1979 and increased to 3.25 inches in 1980. Thus, precipitation has been relatively constant in the spring, but increased almost one and a half inches in the summer over the three year period (Figure 7-1; Table 7-1).

It should be noted that the increased precipitation corresponded with a change in the number and intensity of precipitation events. There has been a decrease in the number of precipitation events during the summer season from 24 events in 1978 to 13 events in 1980 (Table 7-1). This occurred simultaneously with the increased precipitation during the summer period (Figures 7-1 and 7-2).

The range productivity and utilization sampling program is conducted in late August or early September, at the end of the summer season. Over the three year period of 1978-1980, total productivity of all vegetation types sampled increased from 126 kg/ha to 195 kg/ha (Table 7-2). Range productivity increased

Table 7-1. Monthly Precipitation Data and the Number of Precipitation Events for 1978, 1979, 1980, Tract C-a[1/]

	Precipitation Amount (No. of Precipitation Events)		
	1978	1979	1980
Months			
January	1.18 (7)	0.73 (9)	1.10 (6)
February	0.75 (9)	0.35 (2)	1.12 (4)
March	1.99 (10)	1.66 (6)	1.77 (7)
April	1.56 (8)	0.71 (3)	1.16 (4)
May	0.72 (6)	3.07 (6)	2.06 (2)
June	0.81 (3)	0.39 (1)	0.06 (1)
July	0.44 (4)	0.80 (5)	1.22 (6)
August	0.57 (7)	1.09 (2)	1.97 (4)
September	0.68 (3)	0.12 (2)	0.68 (3)
October	0.20 (1)	1.29 (3)	1.28 (2)
November	2.06 (4)	1.02 (3)	0.42 (2)
December	1.35 (5)	0.42 (3)	0.29 (2)
Seasons			
Spring (Mar., Apr., May)	4.27 (24)	5.44 (15)	4.99 (13)
Summer (Jun., Jul., Aug.)	1.82 (14)	2.28 (8)	3.25 (11)
Fall (Sep., Oct., Nov.)	2.94 (8)	2.43 (8)	2.38 (7)
Winter (Dec., Jan., Feb.)	3.28 (21)	1.50 (14)	2.51 (12)
Total Precipitation	12.31 (67)	11.65 (45)	13.13 (43)

[1/] Precipitation Data is measured in inches. Data collected from a wedge gauge.

Figure 7-1. Site 1 Precipitation, Tract C-a, 1978-1980 Using the Wedge Gauge Measurement Technique

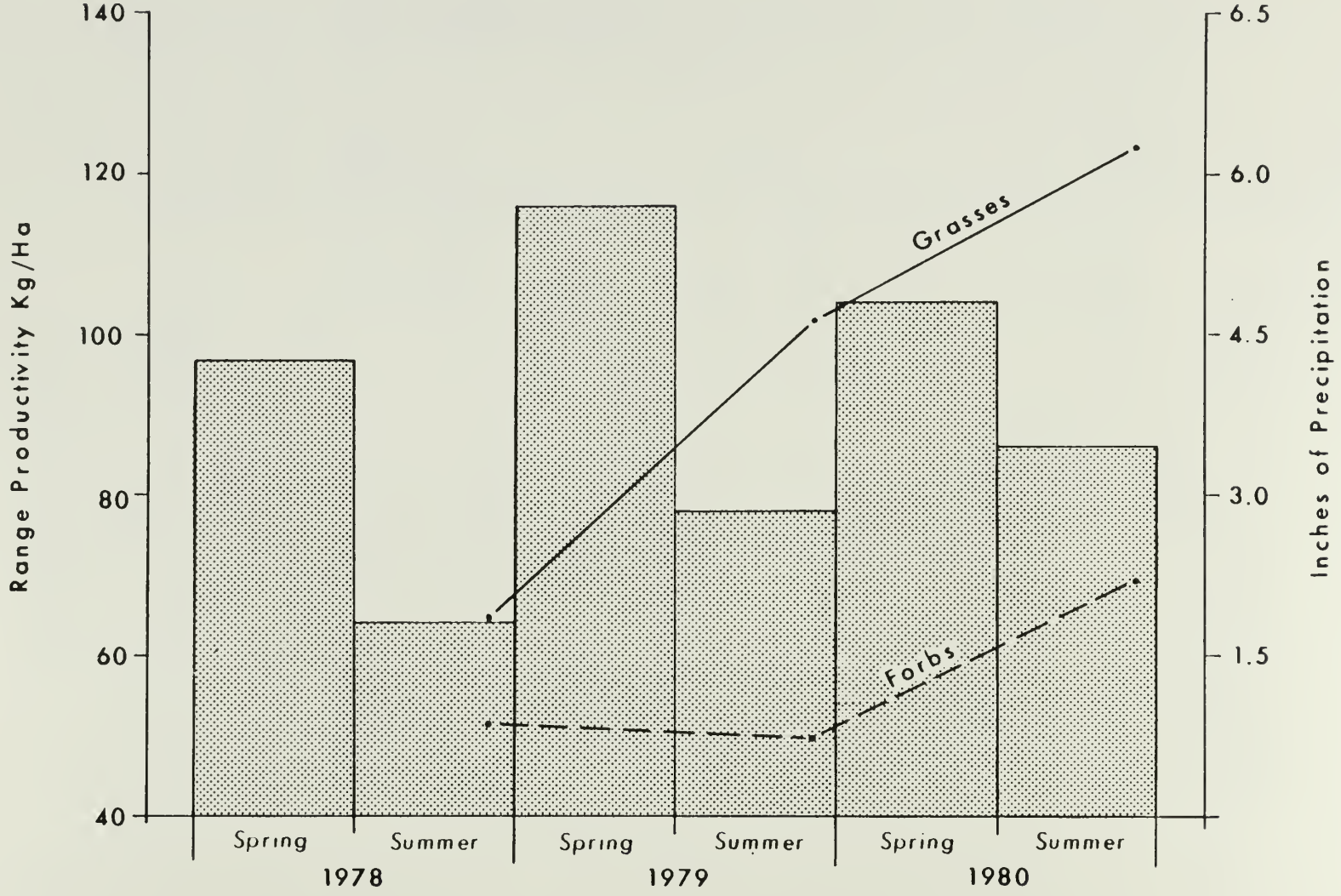

Figure 7-2. Range Production by Growth Form and Spring and Summer Precipitation

Table 7-2. Range Production (standing crop, dry weight, kg/ha) for Grasses and Forbs in Caged Plots Within Three Vegetation Types for 1978, 1979 and 1980

	Year		
	1978	1979	1980
Total Range Production (kg/ha)			
Mixed Brush - Grasses	99	140	159
Mixed Brush - Forbs	111	104	132
Pinyon-Juniper - Grasses	26	34	43
Pinyon-Juniper - Forbs	18	18	30
Upland Sagebrush - Grasses	85	132	157
Upland Sagebrush - Forbs	40	42	62
Average Grass Production	70	102	120
Average Forb Production	56	55	75
Total Range Production	126	157	195

19.7 percent between 1978 and 1979, and 19.5 percent between 1979 and 1980. Broken down by growth forms, the relative increase for grasses was 31.4 percent between 1978 and 1979, and 15.0 percent between 1979 and 1980. Grass production increased in all three vegetation types. Forb production decreased 2.0 percent between 1978 and 1979, and increased 26.7 percent between 1979 and 1980 (Table 7-2, Figure 7-2). Forb production over all three years is considerably less than grass production even though the number of forb species encountered is greater than that of grasses (Table 7-2; Figure 7-2).

Table 3-8 (Section 3.1-C) and Appendix 3-1.4 indicate that between 1978 and 1980 there was a significant difference in grass production for all three vegetation types. Increased grass production can be seen in Table 7-2. Dominant grass species encountered in the productivity analyses were wheatgrass species (including Agropyron smithii) and Indian ricegrass (Oryzopsis hymenoides). These species have high livestock palatability, fair to good drought tolerance, and are adapted to most soil textures (Long 1978). These grass species are considered cool season species that exhibit good growth in the early spring, followed by reduced growth in the early summer months and increased growth in the late summer and early fall.

Grass production and the amount of precipitation in the summer season have increased between 1978 and 1980. Forb production during the summer season has fluctuated in the same time period (Table 7-1; Figure 7-2). Precipitation amounts and the number of precipitation events during June have decreased since 1978, resulting in less moisture during the early summer. Precipitation amounts and number of precipitation events in July have increased since 1978. The August precipitation amounts have increased while the number of precipitation events has decreased. The resulting heavy precipitation events are likely to result in an increased amount of runoff and less recharge of moisture within surface soils. Grass species with extensive rhizomatous root systems may have a competitive edge over other plants under the conditions stated above. The peaks in precipitation (May and August) correspond to the peak growing periods for cool season plants (Figure 7-3).

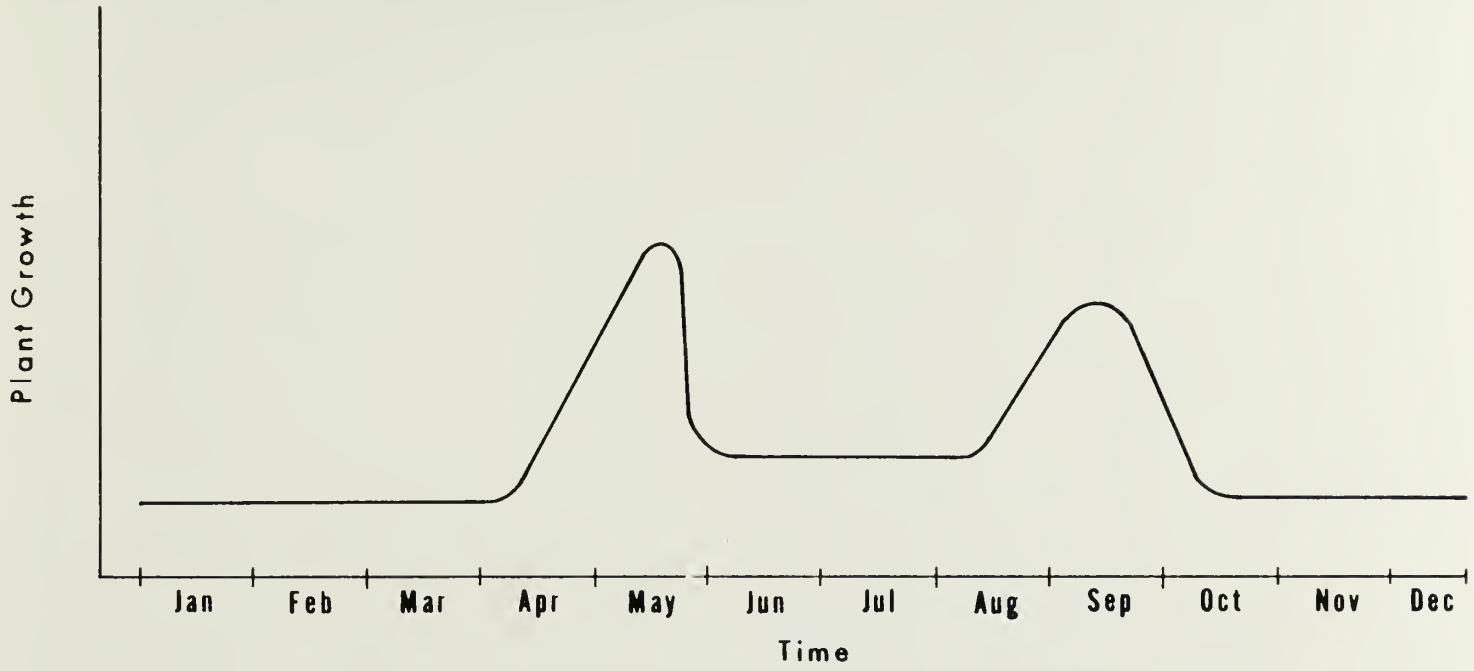

Figure 7-3. Typical Growth Pattern for Cool Season Grasses Such as Agropyron Species and Oryzopsis Species

The interactive components of range production and precipitation over the 1978 to 1980 time period are a combination of many possible mechanisms. Several possibilities are summarized below:

- Increases in the summer precipitation from 1978 to 1980, primarily in the months of July and August, correspond with an increase in the grass production. This may be a function of the competitive advantage afforded grass species with extensive rhizomatous root systems (e.g. Western wheatgrass).

- Another interactive component may be the result of a seasonal interaction. Cool season plants exhibit a bimodal growth pattern similar to that in Figure 7-3. The bimodal growing seasons correspond with increased moisture in the spring and late summer. These may be the ideal conditions which allow for increased biomass of dominant grasses. Growth of annual forbs would be favored in the spring and early summer when moisture is more readily available. If these plants complete their life cycle during this period, then late summer sampling may not detect the true production of these species.

7.2 INTERACTION OF THE MULE DEER POPULATION AND BROWSE UTILIZATION

In order to adequately describe the relationship between browse (primary production) and mule deer (Odocoileus hemionus) (a primary consumer) a discussion of each of these components is necessary to establish changes and possible trends over the study period (1978-1980).

Examination of the utilization of browse species that are considered important for mule deer is an integral part of the RBOSC monitoring program. A detailed discussion of the 1980 sampling year is presented in Section 3-1.D of this report. Browse utilization is assessed in the late spring on Tract C-a within three vegetation types; mixed brush, pinyon-juniper and upland sagebrush. Figures 7-4 to 7-6 show the yearly trend in the utilization of selected browse species in each of these habitats. Utilization within the mixed brush vegetation type increased slightly from 1978 to 1979 but declined to below the 1978 levels in 1980. The pinyon-juniper vegetation type exhibited relatively high utilization in 1978 followed by a decrease during 1979 and 1980. The sagebrush habitat type showed a trend similar to that of the pinyon-juniper vegetation type (Table 3-23, Section 3-1.C, Figure 7-4).

A detailed discussion of the mule deer program is presented in Section 3-2.C; Appendix 3-2.4 shows a breakdown of pellet groupings by vegetation type for the winter distribution over the period 1978 to 1980. All pellet counts were made in the exact same location for all three years. Pellet counts have decreased in the mixed brush and sagebrush habitats since 1978. In the pinyon-juniper vegetation type there was a slight increase in the 1979 pellet count and a decrease on the 1980 count. Figures 7-4 to 7-6 show the general decline in the number of pellet groups counted in each of the three browse vegetation types.

The interactive components between these two programs show an interesting set of possible trends (Figures 7-4 through 7-6). Figure 7-4 shows that as the mule deer population decreased between 1978 and 1980; at the same time, mixed brush utilization fluctuated. Mixed brush utilization exhibited a slight increase from 1978 to 1979 and a slight decrease from 1979 to 1980. One explanation seems to adequately account for the relative changes in the mixed

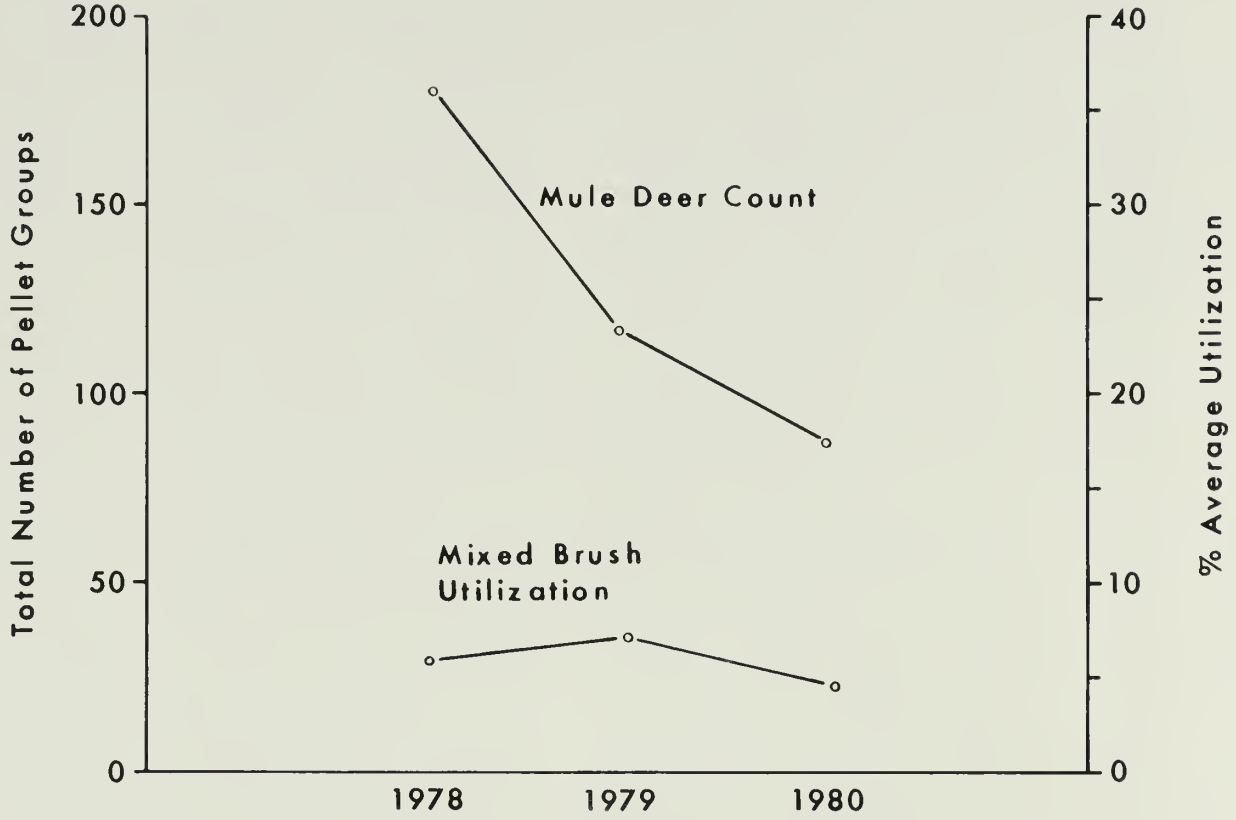

Figure 7-4. Plot of Mule Deer Pellet Counts and Average Percent Utilization in the Mixed Brush Vegetation Type

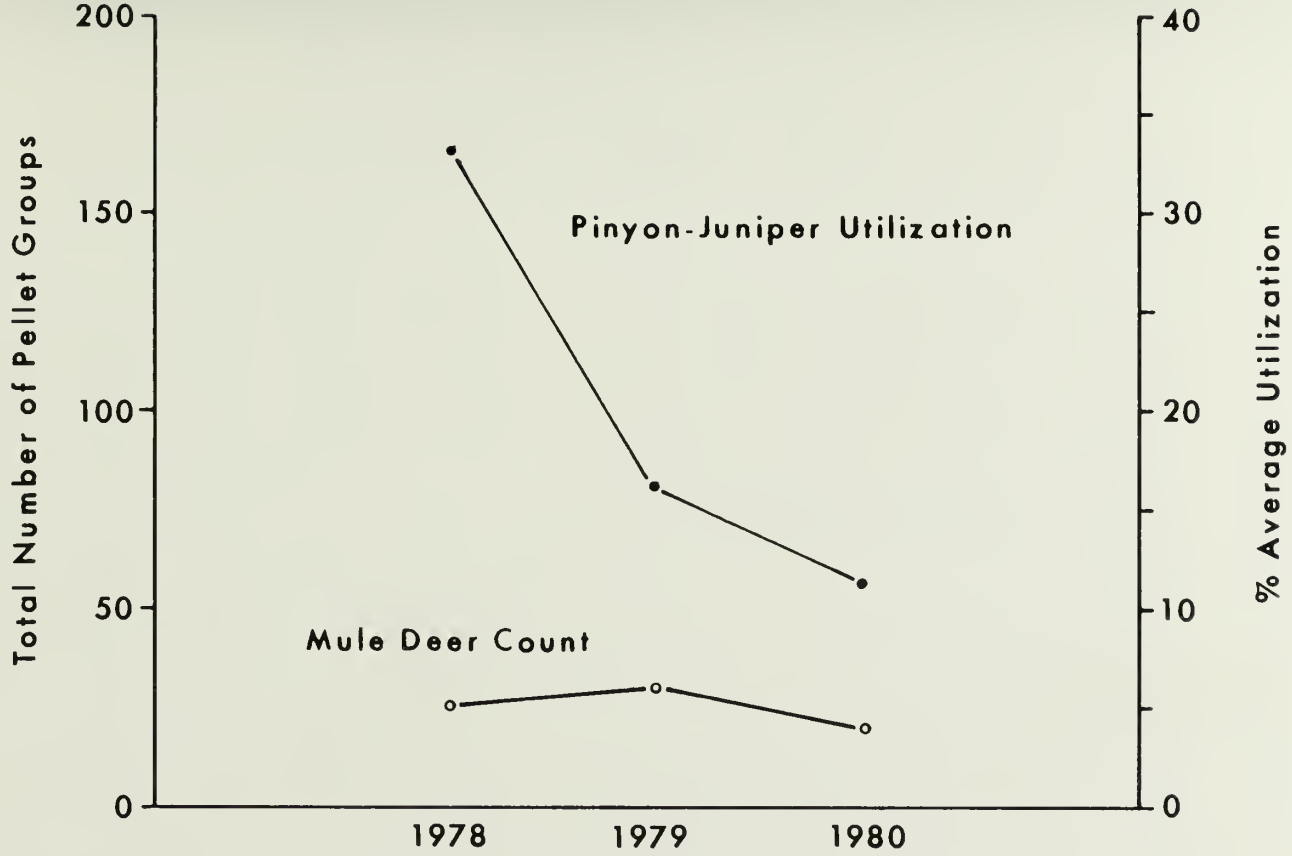

Figure 7-5. Plot of Mule Deer Pellet Groups and Average Percent Utilization in the Pinyon-Juniper Vegetation Type

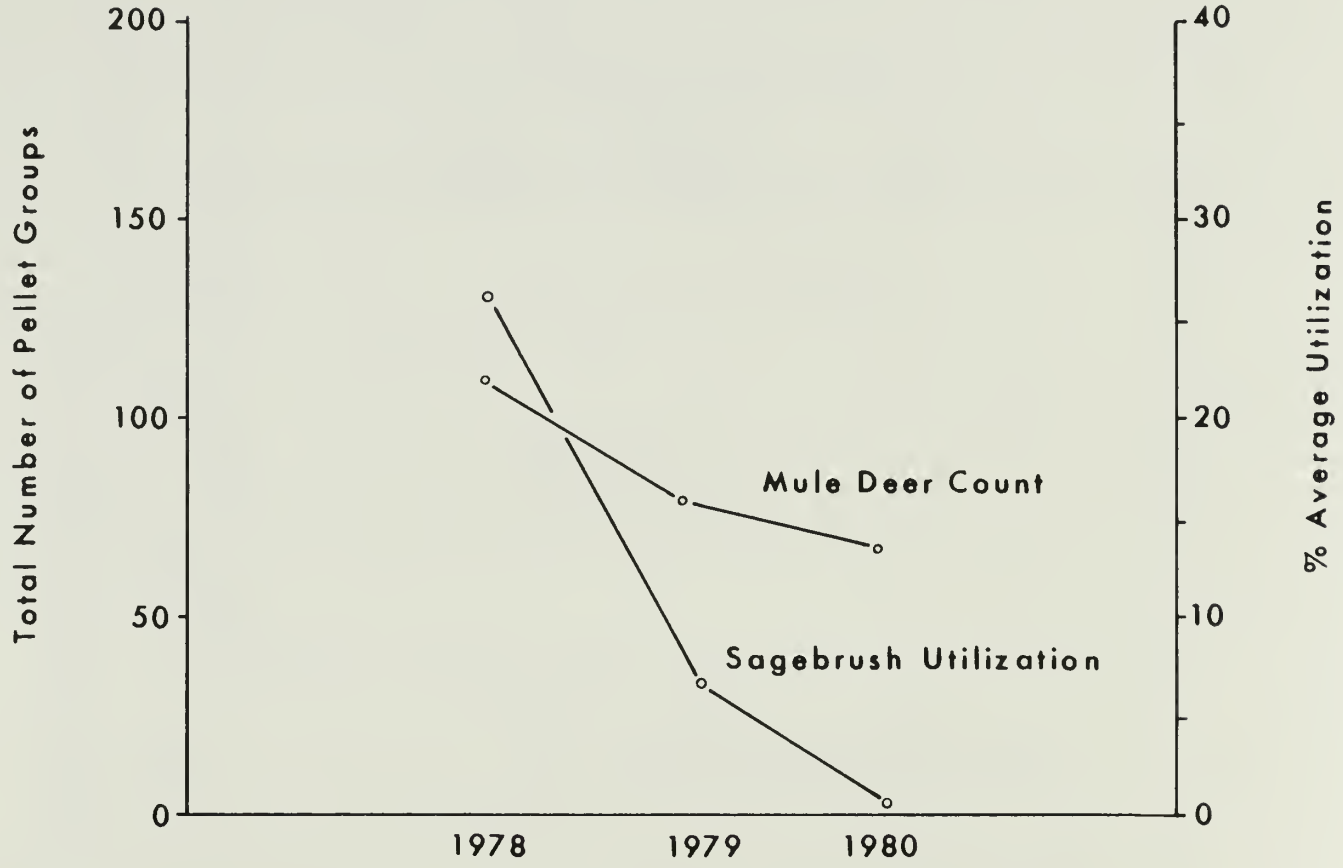

Figure 7-6. Plot of Mule Deer Pellet Groups and Average Percent Utilization in the Sagebrush Vegetation Type

brush utilization. It was previously stated (RBOSC 1980) that declining mule deer numbers within the study area have been influenced by increased snow depth and/or mortality during hard winters. Increasing snow depth may have resulted in reduced availability of the mixed brush type for mule deer use because the type is typically found on north-facing slopes which retain heavy snow cover. Thus, utilization may be effected by winter conditions.

Figure 7-5 shows declining utilization of the pinyon-juniper type and relatively little change in mule deer numbers within the type over the period 1978-1980. This situation contrasts with the overall decline in the mule deer population. The fact that mule deer numbers changed relatively little between 1978 and 1980 in the pinyon-juniper vegetation type may be a reflecion of deer movements. While the deer population exhibited a decline over three years, the survivors may have utilized the pinyon-juniper vegetation type more heavily. The pinyon-juniper habitat probably affords more protection from inclement weather than do other vegetation types and is generally found on south-facing slopes, which have low snow cover. Reduced snow cover, while allowing for deer mobility, provides less moisture and therefore less browse. The pinyon-juniper vegetation type may have attracted large numbers of deer seeking protection during the severe winter of 1978-1979, but the deer may have used other vegetation types for feeding.

Figure 7-6 indicates a decline in both the mule deer population and sagebrush utilization. This may be the result of reduced availability of browse species due to increasing snow depth and/or subsequent reduction in mule deer populations as a result of mortality during harsh winters.

7.3 SUMMARY

Precipitation, range production and browse utilization are three interrelated components of the Tract C-a ecosystems. Measured increases in range productivity appear to correspond to changes in the amount and distribution of precipitation. The peak periods of precipitation also appear to correspond to the peak growing pattern of cool season plants. This indicates that precipitation is one of the many limiting factors affecting vegetation biomass.

The decreases in the mule deer population from 1978-1980 correspond with the decrease in utilization of selected browse species in the three vegetation types sampled. Severe conditions during the 1978-1979 winter resulted in a winter kill of the mule deer and subsequent reductions in the deer population. It appears that this population decrease resulted in a corresponding general decrease in browse utilization.

Literature Cited

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SECTION 8
SUMMARY

Both air quality and meteorological data were collected during the reporting period. The major event related to air quality occurring within this period was the burning of Retort 0. The maximum concentration of SO_2 (the major air pollutant of concern released from the retort) measured during the burn was 0.022 ppm at Site 1. Since this SO_2 concentration was measured during easterly wind conditions (which would transport the stack emissions in the direction of Site 1), it is quite likely that this measurement resulted from the Retort 0 burn. It should be noted, however, that this concentration is near the threshold of detection of the instrument, being only about four percent of full scale.

The ozone concentrations found on the tract varied from 0.003 to 0.070 ppm, well below the National Ambient Air Quality Standard (NAAQS) for ozone of 0.12 ppm. The diurnal cycle in ozone concentrations was greater at Site 3 than at Site 1. The larger cycle at Site 3 results from nighttime inversions which develop within the gulch in which Site 3 is located. The inversions effectively seal off the gulch from exchange with the rest of the atmospheric boundary layer, allowing ozone destruction reactions to reduce the ambient ozone concentrations at night.

The source of the relatively high ozone concentrations measured at the tract has not been definitely identified, although these concentrations have been found to be typical of many other remote locations. There has been no evidence of local photochemical production from either natural or anthropogenic sources.

Total suspended particulates (TSP) did not exceed the NAAQS during the current year. Multiple and stepwise regression analyses were carried out on the particulate data, using a combination of meteorological and site activity variables. The highest correlations were found using the annual rather than the seasonal TSP data sets. Approximately two-thirds of the annual variability of TSP concentrations could be explained by the meteorological and site activity variables. This is very similar to the results of regression analyses performed for the two previous years.

Site activity parameters ranked no higher than third in explaining the variability of TSP concentrations, and contributed only minor improvements to the regression

analysis. Temperature was by far the most successful predictor, largely because it has an annual cycle similar to the TSP data, and it serves as an indicator variable for other important parameters, such as soil moisture.

Review of the 1980 meteorological data revealed that 1980 meteorology was similar to previous years. Precipitation at the tract averaged approximately 12 inches during the current year. The temperature range of 48 C (-16 C to +28 C) measured during the current year at Site 1 is typical of continental sites. Wind speed at the tract has been relatively low, reaching a maximum of 32 mph at the 10-m level at Site 1. Winds have been predominantly out of the west and southwest.

The 1980 visibility monitoring program indicated a slight increase in visual ranges in the Piceance Creek Basin. The mean annual visual range during 1980 was 85 miles, which compares with visual ranges of 79 or 80 miles measured during the three earlier years of monitoring. There is a large day-to-day variability in the visual range, but this is primarily a result of widely varying meteorological conditions. The maximum visual range measured in 1980, 176 miles, was the highest value in the four years of monitoring. Visual ranges near 150 miles were also recorded during each of the three previous years. These values approach the theoretical limit of visual range in the atmosphere (200 miles).

Two noise surveys were taken during the reporting period. The measured sound levels generally ranged from less than 30 dBA (the threshold of the instrument) to 50 dBA, except near the main construction area (adjacent to the headframe), which averaged 71 dBA. If the measurements taken near the main construction area are excluded, these sound levels are comparable to data taken during the baseline period.

The components of the Terrestrial Monitoring Program examined during the December 1979 through November 1980 reporting period include vegetation type mapping and stress, phytosociological, range production and utilization, browse utilization and condition, small mammal, avifauna, mule deer and feral horse studies.

Color infrared photographs taken during 1980 showed only minor variations from data collected during 1979. Apparent decreases in moisture were noted in portions of Box Elder Gulch and to the north of Dry Fork of Corral Gulch. Apparent increases in moisture were noted on portions of Sagebrush Ridge and to the northeast of the MIS Area. These differences seem to be due in part to variations in processing and/or photographic printing between the two years. Increased herbaceous vegetation on some revegetated areas also was evident. Data seem to indicate that dewatering and subsequent reinjection and/or discharge of water on Tract C-a during the reporting period have not altered, to any large degree, the vegetational communities which were present on tract during the 1979 sampling period.

Phytosociological studies were conducted on 10 transects (5 control, 5 treatment) within the upland sagebrush vegetation type on and adjacent to Tract C-a. Coverage of trees and shrubs averaged 23.6 percent in the control area and 31.6 percent in the treatment area. Sagebrush (Artemisia tridentata) was the dominant shrub on both areas. Density of sagebrush averaged 6060 stems per hectare on the control area and 7190 stems per hectare on the treatment area. Coverage of pinyon pine (Pinus edulis) and juniper (Juniperus osteosperma) was low on both the control and treatment areas. Coverage of herbaceous species was 44.8 percent on the control area and 32.4 percent on the treatment area. Bluegrass (Poa spp) and wheatgrass (Agropyron spp) species were the dominant grasses on both areas. The prominent forbs on the control area were the northern sweetvetch (Hedysarum boreale) and lupine (Lupinus argenteus). The most prominent forb species on the treatment area was Hoods phlox (Phlox hoodii). Statistical comparisons of arcsine transformed coverage estimates for forbs, grasses, shrubs and trees (lumped by growth form) between control and treatment areas, as well as among transects within each location, showed no significant differences ($\alpha = 0.05$).

Range productivity and utilization studies indicated that production ranged from 73 kg/ha in the pinyon-juniper to 291 kg/ha in the mixed brush vegetation type. Production of grasses exceeded that for forbs in the three vegetation types sampled. Wheatgrass (Agropyron spp), Indian ricegrass (Oryzopsis hymenoides), and bluegrass (Poa spp) were the dominant grasses in all three

vegetation types. Composition of forbs among the three vegetation types was variable. Bastard toadflax (Comandra umbellata), false buckwheat (Eriogonum spp), northern sweetvetch (Hedysarum boreale) and lupine (Lupinus argenteus) were dominant in the mixed brush type. Arrowleaf balsam root (Balsamorhiza sagittata) and goldenweed (Haplopappus nuttallii) were the most common forbs in the pinyon-juniper type. The upland sagebrush type had dominant forbs found in both the mixed brush and pinyon-juniper types. These species included milk-vetch (Astragalus spp), Comandra umbellata, Haplopappus nuttallii, and Lupinus spp.

Statistical comparisons of range production among transects within respective vegetation types for 1980 indicated that there were significant differences ($\alpha = 0.05$) in grass production for all three types. Forb production was significantly different within the mixed brush and pinyon-juniper types. Comparisons among years (1978, 1979, 1980) by vegetation type indicated that grass production was significantly higher for 1979 and 1980 than for 1978 within all three vegetation types. No significant differences were noted in forb production within any of the vegetation types sampled during the same period.

Forage utilization among the three vegetation types was variable. Within the mixed brush type utilization was relatively constant over three years, ranging from 29 percent in 1979 to 31 percent in 1980. Utilization within the upland sagebrush type increased from 36 percent in 1978 to 40 percent in 1980. A marked decrease in utilization was evidenced within the pinyon-juniper vegetation type, from 48 percent in 1978 to 10 percent in 1980.

Browse studies indicated that the weighted average percent utilization ranged from 1 percent in the upland sagebrush to 10 percent in the pinyon-juniper vegetation type. Utilization in all vegetation types decreased relative to 1979 data and is the lowest recorded in five years of study. Results of statistical analyses using arcsine transformed estimates of leader utilization among years (1978, 1979, 1980) by individual browse species indicate significant differences ($\alpha = 0.05$) in use of serviceberry (Amelanchier utahensis) and mountain mahogany (Cercocarpus montanus) within the mixed brush type; sagebrush (Artemisia tridentata), pinyon pine, bitterbrush (Purshia tridentata),

and mountain mahogany within the pinyon-juniper type; and sagebrush within the upland sagebrush vegetation type. All of these species except for mountain mahogany in the mixed brush type had significantly lower leader use during 1980 than during 1978. Variations in utilization between 1980 and 1979 generally were not significant. Lower use in 1980 relative to 1978 may be due to decreases in the mule deer herd size between the two years. The smaller mule deer population combined with the relatively harsh 1978-79 winter season have resulted in the continued decline in browse use since May 1978.

Range condition ratings based on age class and/or hedging class were similar to those evidenced during 1979; however, there is some indication that range condition is improving. Improvements are evident primarily in ratings based on hedging classification, and are probably due to lower browse utilization. Because the RBOSC browse studies are designed to census the same individuals on a yearly basis, one would not expect to find large changes in range condition ratings based on either hedging or on age classification.

The small mammal species most frequently captured during this monitoring period were the deer mouse (Peromyscus maniculatus) and the least chipmunk (Eutamias minimus). These same species also were captured most frequently during baseline studies and in 1979 MDP studies. No change which could be attributed to tract development could be detected in the small mammal population within the study area.

More species and a higher number of birds were seen in the pinyon-juniper habitats than in the sagebrush habitats in both 1979 and 1980. The pinyon-juniper habitat has a more heterogeneous vegetative community structure than the sagebrush habitat and can support a more diverse avifauna population. Commonly observed bird species in the pinyon juniper habitats were the black-throated gray warbler (Dendrocia nigrescens) and the chipping sparrow (Spizella passerina). Commonly observed species in the sagebrush habitats were the Brewer's sparrow (Spizella breweri) and the green-tailed towhee (Chlorura chlorura). Differences in numbers of birds observed between years are within expected normal fluctuations in densities.

Mule deer (Odocoileus hemionus) density, estimated from pellet group counts in the RBOSC study area, has declined from 51 deer per square mile in 1978 to 28 deer per square mile in 1980. This decline is probably a result of the severe winter kill of 1978-79. Effects of this winter kill will probably be evident in the density estimates for several years. The estimated deer density has been highest in the tract development portion of the study area for each of the three years of the MDP. Explanations for this high density are uncertain. Continued study will further the knowledge of the factors influencing mule deer use of one area in preference to another, and this information will then aid in planning reclamation and mitigation efforts on and adjacent to Tract C-a.

Thirteen deer killed by collisions with vehicles were found along Rio Blanco County Road 24 during the reporting period. Signs warning drivers of deer road crossing areas were erected along this road in an effort to reduce this loss.

Twenty four bands of feral horses totaling 120 individuals were counted in the RBOSC study area in January 1980. Ninety-nine horses in 21 bands were counted in 1979. A moderate winter and good foal success probably account for this increase. The removal of horses from the area by the BLM may cause a reduction in the number of horses counted in subsequent surveys.

The Tract C-a area does not provide critical habitat for any endangered wildlife. Bald eagles are commonly seen foraging in the area during moderate to severe winters. This species ranges over a large part of western Colorado during the winter months. Protected species, such as the golden eagle and the raven, are commonly seen in the area throughout the year.

Physical parameters examined at each of the aquatic sampling stations indicate seasonal as well as annual variability. Few trends or major changes in the physical measurements can be detected from the data. Stations 13 and 14 experienced an increase in the volume of flow which was probably due to operational water discharge into Corral Gulch. As a result, the depth and width of the stream channel and velocity of flow increased at Station 13. Higher turbidity recorded at this location was probably a result of the additional discharge.

Water quality measurements made in 1980 indicate no large changes in White River water quality upstream or downstream from its confluence with Yellow Creek. Examination of the 1980 data, as well as the data collected in the baseline and early monitoring studies, also shows no major differences in the water quality at aquatic sampling stations on or near Tract C-a. All analyses were performed according to EPA standards.

A total of 201 periphyton taxa consisting of 157 diatoms (Bacillariophyta), 26 green algae (Chlorophyta), 1 yellow-green alga (Chrysophyta), 12 blue-green algae (Cyanophyta), 2 euglenoids (Euglenophyta), and 3 red algae (Rhodophyta) was identified from the periphyton collected during 1980.

Mean density values ranged from a high of 10,196 units/mm^2 at Station 29 to a low of 194 units/mm^2 at Station 13. Annual variations in periphyton densities occur on a seasonal basis and are directly related to such highly variable environmental parameters as current velocity, temperature, light, spring runoff, turbidity and substrate type. The 1980 density and biomass estimates at Station 13 were generally lower than the 1979 values, but the 1980 estimates for all other stations were higher than in 1979. The 1980 estimates for Station 13 were the lowest recorded since the beginning of RBOSC aquatic studies, probably due to the surface discharge and subsquent substrate scouring which resulted.

During baseline studies, Achnanthes spp. (primarily Achnanthes minutissima) dominated the periphyton at Station 13. Taxa dominant at this station during the 1980 MDP studies but not during the baseline studies were the blue-green alga, Phormidium sp., in the spring, the green algae, Cladophora sp., Microspora sp., Spirogyra sp. and Zygnema sp. in the summer, as well as the red alga, Batrachospermum sp., in the fall. This change in dominant species may have been due to the increase in turbidity and flow of water at Station 13. Differences in species dominance are not uncommon in aquatic communities that have a high degree of variability in environmental parameters such as stream velocity and turbidity.

Stations 20 and 21 on Yellow Creek have spring and fall periphyton communities which appear to be dominated by a group of diatoms whose relative abundance varies annually. The summer trend of green algal dominance at Stations 20 and 21 has increased during the MDP monitoring studies from 1978 through 1980. Station 27 on the White River, upstream from any project influence, has shown changes in periphyton density, biomass and species diversity similar to Station 29 which is on the White River downstream from the confluence of Yellow Creek. Therefore, it appears that Tract C-a project activities are having little or no effect on the periphyton communities of the White River.

Corral Gulch is directly affected by project related activity on Tract C-a. Station 13 is located in an unstable area characterized by fluctuations in flow, silt load and dissolved solids. The macroinvertebrate fauna is indicative of disturbance and is tolerant of such conditions. Station 14 is located in an unstable area where water level and velocity have changed several times due to the breaking of the dam and activities related to its repair. The fauna here, too, is indicative of disturbance.

Yellow Creek is a small creek affected by natural fluctuations in flow and silt load. Stations 20 and 21 have similar macroinvertebrate communities characterized by organisms tolerant of unstable conditions. It appears that Tract C-a activities do not affect the biota of lower Yellow Creek.

The White River does not appear to have been directly affected by mining activities on Tract C-a. The macroinvertebrate communities at Stations 27 and 29 can be described as diverse, stable and normal for a river of the size and location of the White River.

The hydrology monitoring program produces information applied to several needs:

- Stipulations of the lease and conditions of approval from the OSO
- Engineering design input for mine and water handling systems

- Evaluation of the need for environmental mitigative measures
- Permit requirements

Data on surface streams and groundwater have been collected since 1975. The 1980 report year data have been compared to data from previous years to identify and to evaluate any trends. The program includes monitoring at numerous installations, including stream gaging stations, springs and seeps, erosion and sedimentation stations, alluvial and deep aquifer wells, surface impoundments, surface discharges, reinjection system, and dewatering wells. The natural hydrologic and hydrogeologic environment is monitored as well as facilities associated with oil shale activities.

Six USGS stream gaging stations were included in the 1980 monitoring program. Continuous monitor data (flow, specific conductance, pH, and temperature) for 1980 were not available from USGS for this report. Water quality data were available for all but the Dry Fork Station (A).

When compared to the baseline period, differences in water quality observed in 1980 were generally not appreciable, particularly for mean values. Differences noted in specific conductance and concentrations of several major inorganic ions and dissolved organic carbon (DOC) in Corral Gulch (east of tract) may be related to occasional mine water discharges in the Corral Gulch watershed. Similar differences from the baseline were noted in the year-end report for 1979. Multiple analysis of variance (MANOVA) indicated that surface flow water quality data for the 1980 water year was significantly different from the baseline only for concentrations of molybdenum and DOC.

Springs and seeps data for 1980 were generally comparable to previous observations. Baseline data on water chemistry collected near the existing sampling sites are presently being evaluated for comparison with current data.

Data collected at alluvial wells showed seasonal patterns comparable to earlier observations. Analysis of physical data showed a general increasing trend in pH since the baseline period. Data reported in 1980 were comparable to 1979

observations. The trend in pH is probably due to several factors, including natural variability, sampling errors, and the discharge of upper aquifer water into the alluvial system. The presently observed slightly alkaline conditions are characteristic of western arid regions and the overall magnitude of the change is small.

Statistical analysis of alluvial water quality data showed significant differences between 1980 and baseline years for several constituents. However, with the exception of specific conductance, pH, and magnesium concentration, the overall mean levels during the baseline were greater than the means for 1980. Similar results were noted in the year-end report for 1979.

Upper aquifer data showed increased pH levels and slightly increased conductivity levels since the baseline period. Similar trends were observed for the lower aquifer. Statistical analysis of upper aquifer water quality data indicated that the 1980 report year was significantly different from the baseline for several constituents. However, the 1980 means were less than baseline year means for all of these except pH, calcium, magnesium, and sulfate. The pH in the lower aquifer was also shown to be significantly greater than baseline pH levels.

Several factors (e.g., natural variability, sampling errors, local changes in aquifer chemical equilibria influenced by the presence of wells, and perhaps general equilibria changes due to dewatering) interact to create the observed changes in the upper aquifer. The changes are considered to be geochemical in nature and not the results of retorting or other development impacts.

Development activities were directly monitored using installations associated with the dewatering/reinjection/discharge system, runoff collection system, and liquid waste impoundments. Where past data on ponds were available, 1980 observations were generally comparable to past observations. The piezometers used to monitor pond seepage were dry by the end of 1980, supporting the conclusion that water previously observed in these was due to natural infiltration from precipitation and not pond seepage.

Surface flow stations during 1980 generally reflected discharges lower than 1979 due to diminished surface discharge from the dewatering system. Conductivity, temperature, and pH levels during 1980 were generally comparable to earlier measurements.

The cone of depression resulting from the dewatering operations was relatively constant throughout 1980. Most of the mine water and discharge from dewatering wells was reinjected during 1980.

Toxicology studies of oil shale and related materials have been and are being conducted to assess the potential health hazards associated with these substances. Studies being conducted by the American Petroleum Institute (API) and the Department of Energy (DOE) are most relevant to RBOSC, as both programs include tests of material from Tract C-a.

In 1976, the API initiated a program to investigate selected toxicological properties of oil shale and related materials. Samples included raw shale from Tract C-a. The first phase of the program is complete and results have been published (Weaver and Gibson 1979). Exposure of test organisms to raw and processed shale dust (two year inhalation studies) showed no evidence of carcinogenesis or progressive fibrotic lung disease. Dermal application of the same material yielded similar results regarding carcinogenicity. Similar dermal tests showed, however, that raw shale oil is highly carcinogenic. It is anticipated that the results of ongoing tests of refined shale oil will show that the refining process reduces this carcinogenicity.

Tests of the teratogenic affects of raw shale, processed shale, and raw shale oil showed no deformities, although some fetal toxicity was noted at the higher doses of raw shale oil. Tests of the mutagenic properties of raw shale oil were positive, weakly positive or negative, and positive in the bacterial assays, mouse lymphoma assays, and cytogenetic assays, respectively.

Tests of the acute oral and dermal toxicity of raw shale oil established respective $LD_{50's}$ (dose at which 50 percent of test animals die) of 8-10 g/kg and 5-20 ml/kg. Histopathological studies of organisms exposed to toxic concentrations revealed extensive liver damage.

Eye irritation, dermal irritation, and skin sensitization tests involving raw and processed shale dust and raw shale oil yielded generally negative results, with the exception of several minor reversible irritation effects. Application of raw shale oil at 0.5 g/72 hours produced dermal irritation.

The tests conducted under the DOE program have been initiated but results are not yet available.

Experiments were initiated during 1975 and 1976 on three revegetation demonstration plots on Tract C-a. Plots R-1 and R-2 serve to demonstrate reclamation feasibility and species adaptability with varying mulch types, fertilizer applications and plot aspects. Plot R-3 was designed to simulate a processed shale disposal site and to test the effects of a reconstructed soil profile (including capillary barrier over processed shale) on reclamation success. Various seeding rates and mulch types also were tested on plot R-3.

Plot R-1, located on a northwestern exposure, had an average coverage of 40 percent for all species encountered during 1980. Planted grass species, primarily Indian ricegrass (Oryzopsis hymenoides) and wheatgrass (Agropyron) species, accounted for 45 percent of this average. For 1980 data, there were no significant differences ($\alpha = 0.05$) in grass coverage among the 16 different treatment combinations. However, based on four years of data, analyses indicated that coverage of planted grasses during 1980 was significantly higher than for all other years. This increase seems to be related to mulch and/or fertilizer treatments. Straw mulch with netting exhibited significantly higher grass coverage than straw mulch followed by crimping. Plots with no fertilizer had significantly higher grass coverage than those fertilized at the time of sowing.

Coverage of planted forb species averaged 9.8 percent and accounted for 24 percent of total coverage on plot R-1. Lewis flax (Linum lewisii), cicer milkvetch (Astragalus cicer var. Lutana) and yellow sweetclover (Melilotus officinale var. Madrid) accounted for the majority of this coverage. For 1980 data, coverage of planted forbs was significantly higher ($\alpha = 0.05$) on plots fertilized at the time of sowing than where no fertilizer was used; however,

there were no significant differences for the other two fertilizer treatments. Comparing all four years of data, 1980 coverage of planted forbs was significantly higher than all other years. Concomitant with this increase, coverage of invaded forbs was significantly lower than for previous years. Forb coverage over four years of data was linked to mulch and fertilizer treatments. Significantly higher coverage of invaded forbs was evident on plots with no mulch and/or hydromulch as compared to either of the straw mulch treatments. Treatment combinations having either no fertilizer or fertilizer at the beginning of the first year of growth exhibited significantly lower coverage of invaded forbs than plots fertilized only at the time of sowing.

Shrub coverage on R-1 averaged 2.9 percent during 1980. Rabbitbrush species (Chrysothamnus nauseosus and C. viscidiflorus) and winterfat (Ceratoides lanata) were the dominant shrub species encountered. No significant differences in shrub coverage were noted among 1980 data but, comparing the four years of study, shrub coverage was significantly higher ($\alpha = 0.05$) in 1977, 1978 and 1980 than during 1976. Based on these data, coverage of shrubs was significantly higher on the no mulch treatments than for any of the mulch amendments. Coverage was similar for most fertilizer treatments but was significantly higher on plots fertilized at the time of sowing than on those fertilized at the beginning of the first full growing season.

On plot R-2 coverage of all species averaged 37.1 percent during 1980. Planted grasses, primarily wheatgrasses and Indian ricegrass, accounted for 41 percent of average vegetational coverage. No significant differences in grass coverage were noted among treatment combinations for 1980 data. However, coverage during 1980 was significantly higher ($\alpha = 0.05$) than for 1976, 1977 or 1978. Coverage of invading grasses was significantly higher in 1980 and 1976 than during the other two years of study. Differences in grass coverage appear to be related to mulch and/or fertilizer treatments. Significantly higher coverage of planted grasses was noted on plots without fertilizer than on plots fertilized at the time of sowing. Coverage of invading grasses was significantly higher on plots with crimped straw mulch than on those with either no mulch or hydromulch.

Planted forbs on R-2 averaged 8.3 percent coverage, or approximately 22 percent of the total coverage. Dominant species were similar to those encountered on R-1. No significant differences were noted among planted forb species for the different treatment combinations based on 1980 data. Invaded forb species exhibited significantly higher coverage ($\alpha = 0.05$) on plots with no mulch than those which had been hydromulched. When data for all years were considered, coverage of planted forbs in 1980 was significantly higher than all other years. Coverage of invaded forbs was similar to that during 1976 but was significantly lower than during either 1977 or 1978. Variations in coverage of invaded forbs over the four year period appear to be related to mulch treatments. Coverage on plots with no mulch was significantly higher than on the hydromulched treatment.

Shrub coverage on plot R-2 averaged 6.2 percent for 1980. Rabbitbrush species and winterfat were the dominant shrubs throughout the plot. Based on 1980 data, no significant differences in coverage were noted among the 16 treatment combinations. For four years of data, shrub coverage was significantly higher ($\alpha = 0.05$) in 1978 than for 1976, 1977 or 1980. Coverage during 1976 was significantly lower than all other years. Significant differences noted over four years appear to be related to mulch treatments. Coverage on no mulch and hydromulch treatments was significantly higher than either of the straw mulched treatments.

Coverage of all species present on plot R-3 during 1980 averaged 33.8 percent on the treatment portion and 39.5 on the control portion. There were no significant differences in coverage between control and treatment plots based on coverage of all species. However, when grass species were compared over four years, 1980 coverage was significantly lower ($\alpha = 0.05$) than during 1978 or 1979. Low coverage in 1980 may be due to clipping plots for biomass determinations in 1979. Wheatgrass species and Indian ricegrass were the dominant planted grasses, and their coverage, as well as that of invading grasses, seemed to be dependent on seeding rates. The high seeding rate resulted in significantly higher coverage of planted grasses than the low rate. Invaded grasses, primarily cheat-grass (Bromus tectorum) and crested wheatgrass (Agropyron cristatum), exhibited significantly higher coverage on plots with the low seeding rate than those with either medium or high seeding rates.

Pubescent wheatgrass (Agropyron trichophorum) and green needlegrass (Stipa viridula) exhibited significant differences ($\alpha = 0.05$) between control and treatment portions of Plot R-3 during 1980. Pubescent wheatgrass appeared to be favored on the portions underlain by processed shale whereas green needlegrass exhibited significantly higher coverage on the control portion. These differences do not appear to be related to differences in soil chemistry and consequently probably are artifacts of the sampling technique rather than the result of differences in the treatment and control plots. Indian ricegrass appears to be favored on plots with hay mulch and/or plots seeded at medium or high rates. Significantly higher coverage of pubescent wheatgrass was noted on plots seeded at the high rate than on those seeded at medium or low rates.

Coverage of planted forb species on R-3 averaged 5.3 percent on control plots and 3.1 percent on treatment plots. Cicer milkvetch was the dominant forb throughout R-3 but Lewis flax and yellow sweetclover also were commonly encountered. Forb coverage (all species lumped over all treatments) during 1980 was not significantly different ($\alpha = 0.05$) from that noted during previous years; however, slight decreases were recorded and are probably due to clipping plots for biomass determinations during 1979.

Based on 1980 data lumped by growth form, coverage for all planted forb species was significantly higher ($\alpha = 0.05$) on plots seeded at low or medium rates than on those seeded at the high rate. Cicer milkvetch, when considered without other planted forbs, followed this trend but the other two planted forb species encountered showed no significant difference in coverage based on seeding rate. Cicer milkvetch also exhibited significant differences between control and treatment substrates. Because no differences were detected in soil chemistry between these substrates, the reasons for variations in coverage are not clear.

Coverage of planted shrub species was 4.4 percent on the control and 3.5 percent on the treatment portion of R-3. Winterfat, fourwing saltbush (Atriplex canescens) and bitterbrush (Purshia tridentata) were common on both control and treatment plots. Coverage during 1980 was significantly lower ($\alpha = 0.05$) than for 1977, 1978 or 1979, and may be due to clipping of plots during 1979. No significant differences in shrub coverage (lumped for all planted species) were noted for

mulch and/or seeding rates. However, when individual shrub species were considered, winterfat had significantly higher coverage on the control plots than on the treatment plots. As noted for other species, this difference in coverage between substrates does not appear to be related to soil chemistry.

No significant differences ($\alpha = 0.05$) were noted between soil samples collected on control and treatment portions of R-3. Analyses included electrical conductivity, boron, fluoride, molybdenum, selenium and arsenic, among others. Data suggest that the reconstructed soil profile is functioning as a satisfactory growth medium and that the capillary barrier incorporated in the profile is inhibiting vertical movement of soluble constituents from Tosco II processed shale into the surface growth medium.

Subsidence monitoring is conducted at Tract C-a to determine if any surface displacement has occurred due to the dewatering effort, retort preparation or burning, or any other unforeseen cause. Monitoring is accomplished by surveys of monuments established prior to retort preparation. All monuments are surveyed for vertical movement every six months and for horizontal movement once a year. Surveys were conducted in June and December of 1980. No monument movement was detected.

The run-of-mine ore stockpile lysimeter study is designed to establish the chemical characteristics of leachate generated from raw shale in the field, and to compare such characteristics with those of leachate generated from raw shale in the laboratory. This comparison will enable a determination of the effects on leachate quality of factors such as percolation rates, wetting and drying cycles, and natural weathering.

The lysimeter study was initiated in June 1980. Lysimeters were installed at depths of 5, 10, and 15 feet. Samples are collected by the USGS after each precipitation event and distributed for analysis. To date, adequate leachate for analysis has accumulated only at the 5 foot level. Results of analysis of approximately 20 liters of this leachate indicated constituent concentrations generally lower than those exhibited by laboratory-generated leachate. This difference may be partially due to the lower average surface area per unit weight of the field shale as opposed to the laboratory shale.

Comparisons of the results of lysimeter leachate analyses to Colorado primary drinking water standards show the concentrations of all trace metals except manganese to be below the standards. Concentrations of nitrate, sulfate, and fluoride exceed the standards, but approximate those exhibited by lower aquifer water at Tract C-a.

The mule deer habitat modification study is designed to determine the feasibility of increasing the wildlife carrying capacity of Tract C-a habitats by application of vegetative manipulation, fertilization, and seeding techniques. Such increases offer a means of mitigating development-related loss of wildlife habitat.

The habitat modification experiment was initiated in October 1980 in Stake Springs Draw on Tract C-a. Two treatment areas were established. Within each area, narrow corridors were chopped in the sagebrush, leaving the vegetation undisturbed between the corridors. Corridors in one area were oriented parallel to the direction of the draw (and most winter winds); those in the other, perpendicular to the same. Half of each area was then seeded with a wildlife-oriented seed mix, and half of each area will be fertilized in the spring of 1981, completing a full range of treatments. Control areas were also established adjacent to each treatment area.

The success of the experiment will be measured by estimating forage production and mule deer utilization. Shrub density and cover and herbaceous cover were estimated prior to treatment, and will be re-estimated after each growing season. Mule deer utilization will be estimated by periodic photographs from an established point. The results of these investigations will be included in future reports.

Precipitation, range production and browse utilization are three interrelated components of the Tract C-a ecosystems. Measured increases in range productivity appear to correspond to changes in the amount and distribution of precipitation. The peak periods of precipitation also appear to correspond to the peak growing pattern of cool season plants. This indicates that precipitation is one of the many limiting factors affecting vegetation biomass.

The decreases in the mule deer population from 1978-1980 correspond with the decrease in utilization of selected browse species in the three vegetation types sampled. Severe conditions during the 1978-1979 winter resulted in a winter kill of the mule deer and subsequent reductions in the deer population. It appears that this population decrease resulted in a corresponding general decrease in browse utilization.

R. 100 W.

R. 99 W.

R. 98 W.

T. 1 S.

T 1 S

T. 2 S.

T 2 S

SITE CLUSTER II

SITE CLUSTER I

Sir Alluvials

Flume 5

Flume 4

Flume 3

Sir Alluvials

Flume 2

Flume 1

Weir 2

Weir 1

G-S M1

G-S M2

G-S M3

G-S M4

GS-M7u

GS-M6u

GS-M5u

GS-M10u

GS-M11u

GS-M12u

GS-M5

Near Confluence of Yellow Creek & White River

SEO Flume 14

G-S S24

24-RdNandS

G-S S11A

84 Ranch Spg V-Notch Weir

Miller Spg

USGS Gage D Physical Met 3

Box Elder Flume Spg

Culvert Discharge

GS-S27

G-S S27A

G-S S4-5

G-S S26

G-S S25

G-S S14

G-S S6

G-S S7

G-S S8

G-S D17

G-S 2-3

G-S 1

G-S 9

G-S 10

G-S 11

G-S S13

G-S 15

CE 701

CE 702

CE 707

CE 708

CE 709

CE 705A

TO-1

AM-3

AM-2A

S2

S31

Stake Spgs Windmill

DUCK CREEK

BIG DUCK

LITTLE DUCK

CORRAL GULCH

ELDER GULCH

BOX ELDER

SPRING GULCH

TAKE GULCH

RYAN GULCH

DRAW

AIRPLANE RIDGE ROAD

WOLF RIDGE ROAD

Legend

- SPRING OR SEEP
- STREAM GAGE
- MONITORING WELL IN ALLUVIAL AQUIFER
- MONITORING WELL IN UPPER AQUIFER
- MONITORING WELL IN UPPER & LOWER AQUIFER
- MONITORING WELL IN LOWER AQUIFER
- EROSION - SEDIMENTATION SITE
- ENVIRONMENTAL SOUND MONITORING SITE
- MINE DEWATERING FLUME
- O.A. MUNSON PIPEYARD
- METEOROLOGICAL & AIR QUALITY MONITORING SITE

- PROTECTED HISTORIC REGISTER SITE
- SITE CLUSTER - AREA OF ARCHAEOLOGICAL SIGNIFICANCE

0 4000 8000
Feet

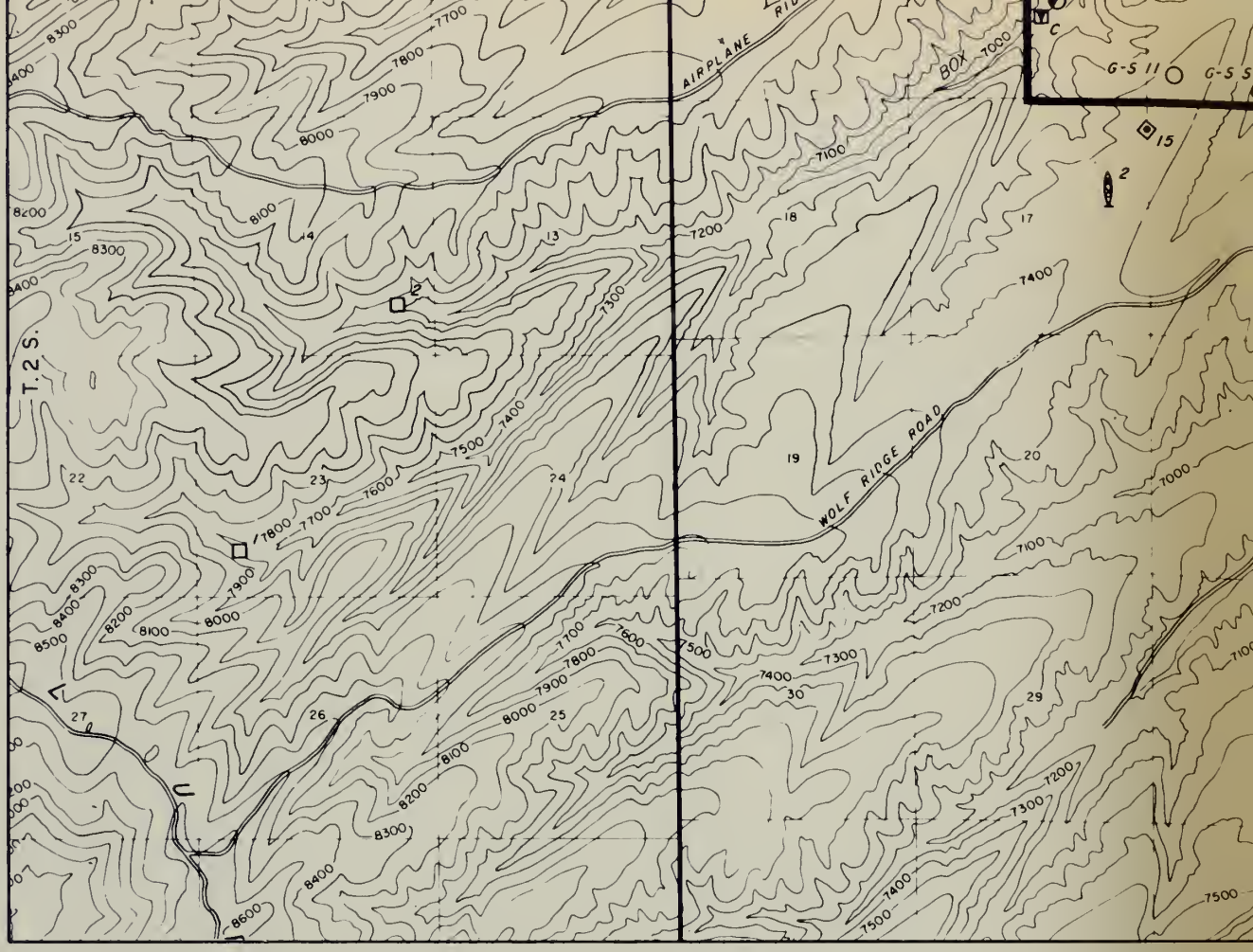
DATE	REVISIONS
8/7/79	ADD 150-004 Rev 0.0.
9/17/80	Field: the new well's have been surveyed in as built

Rio Blanco Oil Shale Company
RIO BLANCO COUNTY COLORADO

ENVIRONMENTAL MONITORING SITES
MAP 1 - PHYSICAL

DRAWN BY JDJ	SCALE 1" = 2000'	FIGURE
DESIGN BY	DATE 8/7/79	E-159A
APPROVED BY GG & WJC		

FILE 2-5-10



Legend

- SPRING OR SEEP
- STREAM GAGE
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- MONITORING WELL IN UPPER AQUIFER
- MONITORING WELL IN UPPER & LOWER AQUIFER
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- MINE DEWATERING FLUME
- D.A. MUNSON PIPEYARD
- METEOROLOGICAL & AIR QUALITY MONITORING SITE

- PROTECTED HISTORIC RE
- SITE CLUSTER - AREA OF

Form 1279–3
(June 1984)

BORROWE

TN 859 .C64 R56 Dec
Nov.80 v.
Modular development
monitoring report

DATE LOANED	BORROWER

USDI – BLM